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THE OBSERVATORIES OF SCOTLAND.

HECTOR MACPHERSON JR.

FOR POPULAR ASTRONOMY.

The climate of Scotland is by no means the best for astronomical observation. Scotland is both a mountainous and a sea-girt country; no part of it is very far from the sea and consequently mists and clouds are not infrequent. As an illustration of this it may be said that in 1905 in Mid and East Lothian, only 149 evenings were classed as clear while 216 were cloudy, according to a record by the writer. Still notwithstanding the climate which by the way is not so much worse than that of England, Scotland possesses some finely equipped observatories; it likewise possesses a 22-inch refractor, one of the largest in the United Kingdom. There are three public observatories in Scotland—two in Edinburgh and one in Glasgow—and a few private ones, among which the Coats Observatory in Paisley stands out conspicuously.

Edinburgh, the metropolis of Scotland, is well equipped with observatories, having within its bounds two of the finest astronomical institutions in the United Kingdom of England, Scotland and Ireland—the Royal Observatory on Blackford Hill, and the City Observatory on the Calton Hill. What is now the City Observatory was formerly the Royal Observatory, and before that it was the property of Edinburgh Town Council. The Council resolved in 1776 to erect an observatory on the Calton Hill 350 feet above the sea-level, and in that year the foundation stone was laid by the Lord Provost of Edinburgh. The Council however, had not enough money to proceed with the work, and the observatory was left in a half-finished condition, in which it remained until 1811. In that year it was acquired by the Astronomical Institution of Edinburgh, who equipped it with instruments and used it for many years for astronomical purposes. At length, in 1834, the Government decided on the creation of the office of Astronomer-Royal of Scotland, and it may be stated by the way, that on October 1, 1834, the director of the Green-

wich Observatory ceased to be "the Astronomer-Royal" without the qualification, "of England"—a fact which English writers have not yet been able to grasp. The first Astronomer-Royal of Scotland was the famous Thomas Henderson, who shares with Bessel the honor of first measuring the distances of the stars. As director of the Observatory, Henderson accomplished much valuable work, and his untimely death in 1844 was a severe blow to Scottish astronomy. His successor, Piazzi-Smyth, was an Englishman although born at Naples; he was a man of considerable ability, but it cannot be pretended that the Royal Observatory was benefitted by his tenure of office, which lasted for forty-four years. A commission which was appointed in 1876 to inquire into the condition of the Observatory recommended that it should be rebuilt and when Piazzi-Smyth retired in 1888, it was decided to erect a new Royal Observatory on Blackford Hill, 400 feet in height, to the south of the city. The new Observatory was equipped largely through the munificence of the Earl of Crawford, a Scottish nobleman, who had maintained for some years a private observatory at Dunecht in Aberdeenshire. On giving up the observatory, he presented its outfit and its magnificent library to the new Edinburgh Observatory. The third Astronomer-Royal, the late Dr. Copeland, who had been assistant to Lord Crawford, personally superintended the erection of the new Observatory, which was opened in April 1896.

The Observatory, which is conspicuous in the landscape of suburban Edinburgh, has a fine collection of astronomical instruments, chief among which is a 15-inch refractor. It is also well equipped spectroscopically. To the spectroscopic side of the science, Dr. Copeland gave most of his attention, and the second assistant, Dr. Halm, has made a considerable reputation in this line of research by his studies of the Sun's rotation, and kindred subjects. The new stars of 1892 and 1901 were attentively studied at the Observatory, and besides this, much attention is given to astronomical photography.

In 1889 the old Royal Observatory buildings were taken over by the Town Council of Edinburgh, and formed into a City Observatory, mainly for educational purposes. The Council placed at its head a director with the title of Astronomer to the City of Edinburgh, and the post was given to the well-known Scottish astronomer, Mr. William Peck. The Observatory is much patronized by the citizens. A good deal of practical work is done by Mr. Peck, who has accomplished a vast amount of useful work in practical astronomy. The Observatory possesses a 22-

inch refractor, the largest in Scotland, which is housed in the detached dome shown in the plate; but the instruments generally used are a 6-inch refractor and a large reflector, both gifts of former Members of Parliament for the city. These instruments are of the finest quality, their construction having been superintended by Mr. Peck who is himself a skilled optician.

The Glasgow University Observatory is the oldest in Scotland. In 1760 a sum of money for the erection of an Observatory was bequeathed to the University by Dr. MacFarlane, a Scotsman resident in Jamica. On the erection of the observatory, a man of conspicuous ability, Alexander Wilson, was placed at its head, and in 1769 it was the scene of one of the greatest discoveries in the astronomy of the eighteenth century, that of the depressed nature of sun-spots by Wilson himself. The Observatory was subsequently directed by Wilson's son, Patrick, who retired in 1799. From 1836 to 1859, it was directed by the famous John Pringle Nichol. Under his direction the site of the Observatory was shifted to its present position on Gilmorehill, Glasgow, and equipped with new instruments. Nichol's successor, the late Professor Grant who was a famous compiler of star-catalogues, still further increased the efficiency of the observatory. At the present time, the chief instruments are a nine-inch refractor by Cooke of York, two smaller refractors—of seven and three and a fourth inches respectively—and a fine twenty-inch reflector. Besides the measurement of stellar positions, which has long been standard work at Glasgow, the study of spectroscopic astronomy, is largely carried on at the Observatory.

There are no observatories in connection with the Universities of Aberdeen and St. Andrews or the College of Dundee. This is much to be regretted, as the climate of Aberdeen especially would be excellent for observation. There is much to be desired in the direction of founding more observatories in Scotland; things are not what they should be. The climate is not ideal, but it is quite good enough for many useful purposes, especially if the laboratory system, which Professor Kapteyn has successfully introduced in Holland, were adopted in Scotland. There are many suitable sites for observatories in the Scottish Lowlands—gentle elevations in the Lothians and the Borders, such as the Berwick Law, near North Berwick, in East Lothian, Tinto Hill in Lanarkshire, or the Dalmahoy Crags, in Mid-Lothian, to mention only a few. A small fraction of the sum which British Governments spend annually on military and naval purposes would suffice to maintain a useful and progressive system

of observatories throughout Scotland, to supplement and assist our older astronomical institutions of which Scotland has every reason to be proud.

RECENT PROGRESS IN THE MEASUREMENT AND REDUCTION OF RADIAL VELOCITY SPECTROGRAMS.

R. H. CURTISS.

FOR POPULAR ASTRONOMY.

For the determination of relative or absolute radial velocities according to Doppler's principle, the direct comparison of similar or, if possible, identical spectra of different sources possesses a distinct and obvious advantage in point of accuracy at least, over any other known method. In solar work, as for example the determination of the Sun's rotational period, this method has met with the greatest success. In the determination of stellar radial velocities, however, no direct comparison of similar spectra simultaneously photographed in one position of the spectrograph is ever possible except in the case of certain binary stars of very limited number. But an indirect and accurate comparison of stellar spectra with similar sources of known velocity can be effected in the simple manner first set forth by the writer in *Lick Observatory Bulletin*, No. 62. It was there suggested that without any change in the prevailing methods of making stellar spectrograms, a standard source of known velocity with spectrum similar to that of the star be photographed with the usual metallic spark comparison spectrum; that the spark lines in the star and standard plates be employed to reduce the two photographs to the same dispersion and to the same zero; and that the corresponding absorption lines and groups on the two plates be then directly compared for the determination of stellar radial velocity.

At Lick Observatory this method has been applied with gratifying results by various observers, with instruments of high and low dispersion. The advantages of the method are beyond question.

At Pulkowa, Belopolsky has carried out an important series of comparisons of the old wave-length method with the new solar

standard velocity method* demonstrating the advantage of the latter for direct and accurate work†.

He first studies the wave-lengths of blends determined from Rowland's data, showing that wave-lengths formed by blending are uncertain at best and, in his case at least, that simple means of wave-lengths of close lines, sometimes of widely different intensities, satisfy his observations much better than the weighted blends. He then carries out a most important series of comparisons between measures of plates of α *Boötis* reduced by the old and the new methods, employing in the new method only one solar standard velocity plate. In the case of the old method Belopolsky, guided by long experience in the use of wave-lengths, selects a list of single lines and blends which bring out the best results in the use of Rowland's tables. That the character of these selected lines is remarkable is seen at once from an examination of the sixteen wave-lengths which were used in the published reduction of the measures of α Boötis according to the wave-length (Campbell-Hartmann) method. Five of these lines are single. Two are considered single which have unresolved satellites of 0 intensity. Eight are blends assigned wave-lengths which are direct means of lines sometimes of widely different intensities (e. g., in one combination a line of intensity 0 is given equal weight with a line of intensity 4.) The remaining line of the sixteen (λ 4325.183) appears to be a weighted mean. Evidently these wave-lengths, the result of great care and study, should place the old method in the best possible light. Nevertheless, in spite of the fact that only one solar standard plate was used, the agreement among the results from the eleven plates as reduced by the new method was slightly superior to that which resulted from the use of wave-lengths selected as described above. This seems an important demonstration of the value of the new method, in which lines are available without study as to wave-length and in which, therefore, time and labor are economized with increase of accuracy in the results.

Belopolsky's paper is concerned with relative velocity. The actual accuracy of absolute velocity determinations by the new

* Belopolsky refers to this method as the modified Vogel method which seems a misnomer. In his earliest method Vogel did use the solar spectrum without comparison as a standard of dispersion and identification but not as a standard of velocity. The so-called modification is therefore a complete change of method. The new method is not an outgrowth of the old one of Vogel.

† Mitt. der Nikolai-Hauptsternwarte zu Pulkowa, Band I, No. 6.

method can be readily tested by comparison of negatives of similar sources of known velocity. This test as effected by Hartmann* and the writer by the comparison of separate solar standard plates is good evidence that the new method realizes all the possibilities of the modern spectrograph.

A long step in advance in the application of the new method has been taken by Hartmann† who has employed an optical device to superimpose the star plate on the standard plate by reflection of the light from two microscope objectives into one occular, while the plates themselves are relatively movable by a micrometer screw. By this means the spark spectra, and the star and Sun spectra on two separate plates can be directly compared for velocity determinations.

The difficulties which are contended with in the use of this device are: the greater requirements in the adjustment of plates on the engine; the effect of the individual peculiarities of one solar standard plate; the danger of error due to the departure from a straight line of the relative dispersion curves of standard and star plates: the independence, in the reductions, of the measures of separate groups of spark lines, which are mutually strengthened when dispersion curves are drawn; and the unavoidability of the assignment of greatest weight to the small regions of spectrum which are adjacent as seen in the superposed negatives. The first difficulty has been met by constructing an engine with every convenience for adjustment. The second can be avoided as far as absolute velocities are concerned by the determination of the accidental errors of one standard plate by comparison with several others. The third can be eliminated by a judicious selection of lines. The fourth and fifth are outweighed by the admission of a greater number of lines into the measures with Hartmann's device. The effect of the fifth disadvantage is minimized by the ease with which different parts of the superposed spectra may be placed in juxtaposition by relative slow motion perpendicular to the direction of the longest dimension of the plates.

The advantages of the spectrocomparator method in the case of solar-type stars both in the saving of time and also in the increase of accuracy are so pronounced as to commend it to all observers. Even in case of stars with isolated or enhanced lines a standard source with similar spectrum (such as a typical bright

* Publ. des Astrophys. Obs. zu Potsdam. Nr. 53.

† loc. cit.

star whose velocity is well determined) can be used with advantage, especially in case of spectrograms of low dispersion, which are thus made to depend on the measures of high dispersion instruments. Indeed it is the low dispersion spectrograph which profits most by the use of the standard velocity method.

Probably most observatories doing radial velocity work will take or have taken steps to acquire "spectrocomparators". The instrument is useful not only for the determination of radial velocities. The important researches depending on the comparison of different spectra for the determination of intensities would be greatly facilitated by the use of this comparator. Undoubtedly other uses will be found for this new instrument which seems already indispensable.

In this connection it is useful to notice that the old Zeiss Scale Comparator furnishes an excellent base upon which to construct with small expense a modern spectrocomparator of a convenient type. With the exception of the microscopes and the divided scale, every part of the old instrument can be used to advantage in the modified one. The present plate carriage must be provided with adjusting devices, and for the divided scale a second plate carriage with accurate screw-micrometer motion in the direction of velocity displacement must be substituted. A microscope system similar to that described by Hartmann can be mounted rigidly and permanently upon the present microscope supports. No motion of the microscope system to and from the spectrogram is required if the negative is properly made: for changes of power can be secured in the eyepieces. This complete spectrocomparator as designed seems to possess the following advantages: though very rigid the instrument is light and easily portable; the material in the base is so compact that light for the illumination of the spectrogram can come to the mirrors from front or side; the tripod base is fastened securely upon a wooden base which permits the instrument to be inclined at any angle to suit the observer's convenience; the slow motion in the direction of the longest dimension of the plate, provided for each plate carriage, makes the addition of all measured velocity displacements mechanical and not only facilitates the measures but also simplifies the reductions. It is possible that the extent of spectrum which can be used in any one setting will be somewhat restricted by optical considerations in this form of spectrocomparator though it seems nearly certain that this possible restriction will never operate as an appreciable disadvantage.

The Zeiss Scale Comparator found its principle use in the

measurement of spectrograms. Most observatories doing radial velocity work purchased the instrument for that purpose. But the recent work of Hartmann shows that the spectrocomparator is a good investment for any observatory where spectrograms of solar type stars are measured even though that observatory numbers among its assets the old Zeiss Comparator or a more modern engine. It seems therefore that the above modifications (which make possible the complete restoration of the old instrument with divided scale in an half hour's time) should prove of considerable practical value.

Allegheny Observatory,
December 22, 1906.

ASTRONOMY OF THE PRESENT TIME.

W. W. PAYNE.

Heretofore we have not been able from the lack of space, to give as full a summary of the important work going on in practical astronomy, at the present time, as is really desirable for the best interest of our readers.

We have felt this lack ourselves, and it is probable, also, that our readers have noticed this deficiency in the limited space that has been given to general notes during the past year especially, although the size of our journal was increased a year ago partly on this account.

It has seemed to us that a brief account of current astronomical work as gathered from Journals, publications and private correspondence to be presented monthly, as a kind of running summary of useful information would be welcome to all classes of our readers. It is also probable that if the attention of astronomers was thus particularly called to our plan and the real need it would supply, their aid to help us to carry it out might be secured. It is deemed wise and timely to try it.

In a brief article, in A. N. 4141, Professor W. H. Pickering calls attention to some interesting things about the lunar crater Linné. One is the apparent enlargement of the crater during the time of lunar eclipse. Several observers have noticed this fact. The explanation of this subjective increase in size of the crater is thought by some, to be due to the deposition of hoar-frost during that time that the direct rays of the Sun are withdrawn, or

while the Moon, is enveloped in the Earth's shadow. To have a decisive reason for this interesting phenomenon more searching observation is needed.

In this connection, Frank W. Very's article on the temperature of the Moon, is in the *Astrophysical Journal* Vol. 24 No. 5 p. 351 in which is found useful information concerning the change of the surface temperature of the Moon during the time of a lunar eclipse. Mr. Very has for many years, made the temperature of the surface of the Moon, a special study by the aid of a very sensitive instrument known by name as the bolometer.

Recent work on the Sun embraces several lines worthy of notice. A. L. Cortie has been studying the relation between the disturbed areas of the solar surface and the solar corona. In the *Astrophysical Journal*, Vol. 24, No. 5, p. 360, he says:—"The present paper gives highly probable evidence that not only in general is a characteristic type of the solar corona associated with the sun-spot and prominence activity, but that definite structures in the corona are associated with definite areas of sun-spots and faculæ."

This statement from so good authority seems to imply a step in advance of views generally held in regard to the general relation of the solar surface to the condition of the corona. It is generally known that when the Sun is in the minimum part of the sun-spot period that the solar corona, as observed in eclipses at such times, is much less active and varied in form than it is when it is passing through the maximum part of its eleven-year spot period. It is also well-known that when the solar surface is agitated unusually, then the chromosphere is likewise correspondingly disturbed. This can be easily and certainly observed by the aid of the spectroscope any clear day. Not so regarding the corona. Observers must wait for the few precious minutes of a total solar eclipse to know definitely about its condition.

The reports of the total solar eclipse of August 30, 1905 have now already been so generally published that reference to belated copies recently received seems scarcely necessary, especially since nothing of special importance is to be found in them.

In the matter of ancient eclipses and what they are worth to modern astronomy, the discussion still goes on. In this Professor Newcomb and Mr. Nevill and Mr. P. H. Cowell are especially concerned. The main point in the discussion is:—In the eclipse calculations shall the secular acceleration of the Sun be adopted, or a secular acceleration of node contrary to gravitational theory.

Mr. Cowell "has preferred the former alternative but clearly intimates that the ancient eclipses afford evidence only of the relative movements of the Sun, Moon and node, and not of the position of the equinox. Professor Newcomb's argument which seemed to weaken Mr. Cowell's conclusion of the value of ancient eclipses as data for modern uses was based on the fact that Airy and others deduced erroneous conclusions from the ancient eclipses, therefore Mr. Cowell's conclusions must be unsound. Mr. Cowell after considering a large number of ancient eclipses, claims that the observations of the Sun between 1750 and 1800 are not sufficiently free from errors to decide between the secular acceleration of the Sun and of the node, and so he claims Professor Newcomb's argument is not necessarily valid. It is difficult to decide which of the disputants is right. At the present stage of our knowledge of the theory involved it may be impossible to do so. We must say that the work of Mr. Cowell seems to be very strong and very probably true in the results so far found. His identification of the eclipse of—647 April 6 as that of Archilochus is especially interesting.

In regard to the planets not much of interest appears lately in regard to the study of surface markings. When the planet Mars is nearest the Earth in July, observations of the surface markings of the planet will be made doubtless. The most interesting work of recent date is the discovery of the new satellites of Jupiter and Saturn. In addition to what was said in our last issue we should have mentioned that Jupiter's sixth satellite was marked and measured December 10, 1904, on a photograph by the Bruce 24-inch telescope of Harvard College Observatory. It was then thought to be a minor planet at its stationary point, and so was not followed. Looking backwards it was also found on a plate taken July 12, 1899. The Lick people made the discovery of the satellite January 5, 1905. It has since been learned that the Harvard observers have found two photographic plates of 1894, and nine of 1899 that had on them the images of this satellite. Systematic study of photographic plates is likely to reveal much useful information.

Work upon the stars is perhaps the busiest field of all for the present-day astronomer. The photographic survey of the heavens is being carried forward as rapidly as could be expected, in view of the large undertaking that it is, and the many different astronomers in different parts of the world that are participating in it. Next to this is the parallax and the radial velocity work

that are now occupying some of the ablest astronomers in the world who are furnished with the largest and the best instruments that could be procured. Yerkes Observatory and the Lick Observatory and the Harvard College Observatory are the prominent places in this country where these lines of investigation are carried forward urgently and successfully. Frost's radial work, Barnard's triangulation survey, Parkhurst's researches in stellar photometry and Burnham's double-star work are signally prominent pieces of research that will carry with them lasting authority in their respective lines. Mr. Parkhurst's quarto volume of about two hundred pages published last October is the only complete work of its kind in this new field, with which we are acquainted. The readers of this publication know of Mr. Parkhurst's work on variable stars for many years, for he had charge of it, and gave it its real prominence in our magazine, because his work was always well done.

In this connection, it is a pleasure to notice the good work being done on variable stars under the direction of Col. E. E. Marwick, director of the variable star section in the British Astronomical Association, a copy of the fifteenth volume of whose Memoirs has just come to hand. The volume contains the sixth report of the section embracing the years 1900-1904 with details of work and light curves that make it a useful reference volume.

So much was given about the right comets of 1906, in our last two numbers, that little important or new remains now to be noticed.

Of the nebulæ much is being written in recent months, especially since the geologists have been turning their attention to the nebular hypothesis in text-book writing and in general articles.

The books by Chamberlin and Moulton, one a geologist and the other a mathematical astronomer, have awakened new interest in the theory of the origin of the cosmos, or more particularly, the genesis of the solar system. These books have already come to the notice of American scholars generally, and European astronomers are also discussing the spiral nebular hypothesis which these American writers have suggested as a better theory, than that of the old Laplace nebular hypothesis.

The equipment of scientists of today in every line is so strong and complete that investigations go forward rapidly and certainly, and the test of new theories are thorough and comparatively speedy.

The minor planet study is now almost a field by itself, because

there are so many of them, they vary so greatly among themselves, and their relations to one another are so complex. At this writing (January 5) 562 have received names for permanent record, and 601 have been numbered, their orbits having been computed and the letters of discovery have reached WT. Readers not well acquainted with the present method of keeping track of the minor planets will easily understand how it is done with a few words of explanation. When the minor planets began to be discovered they were named and numbered; for example Ceres is 1, Flora is 8, Cora, 504 and so on. At first numbers of the planets were surrounded by a circle, later were enclosed in a parenthesis, but now most generally the numbers and names of those known are written without circle or parenthesis.

When, by the aid of photography the discovery of new minor planets came more rapidly, a new method of keeping track of these little bodies became necessary. Roman capital letters were chosen for this purpose and they are used in this way. The first found after the new plan was adopted was called A, the second B, and so on through the alphabet. When the alphabet is once used begin again: the first then will be AA, the next AB and ends AZ; the next series will begin BA and end BZ. When we say the discovery has now reached WT, any one will readily understand how many of these bodies have been found since the new plan was adopted.

The WT discovery is quite recent by Joel H. Metcalf, Taunton Mass., November 23, 1906. Mr. Metcalf has found a new method of photographing these faint planets and he is using it very successfully. He found three planets in five days during last November, on his photographic plates. They may be all new. Whether they are or not will be known when their orbits are computed.

The Watson family of minor planets are endowed so that they may be cared for indefinitely onward. Professor James C. Watson director of Detroit Observatory, Ann Arbor, Mich., when he died left in his will a sum of money supposed to be sufficient to keep track of the twenty-two asteroids which he discovered. The American Academy of Sciences was made trustee of these funds, and the duty of the care of these asteroids was given to Lick Observatory, Mt. Hamilton, California.

THE SHADOW-BANDS.*

EDWIN HOLMES.

In entering upon the consideration of any of the phenomena connected with a total eclipse of the Sun, it is in one sense a great disadvantage to have never seen such an eclipse in action, but, on the other hand, such want of experience is a positive advantage when comparing the observations of others, because we are not then influenced by our own observations, which are naturally as faulty as other people's, and upon which we, naturally also, are inclined to place more reliance than on those of others.

Few persons are so ready to criticize severely their own observations as they are those of others, however fair they may try to be.

The first thing that struck me when reading observations of the shadow-bands was their often very indefinite character, their variableness, and their many apparent contradictions, which make them at first sight less useful than they otherwise might be. As instances, while one observer describes the bands as one inch wide and three inches apart, another at the same place estimated them at ten inches apart. Some describe their motion as being in the same direction before and after totality, others find the motion reversed after totality. Some describe the bands as of uniform width, others say they became narrower as the eclipse deepened; yet others that they became wider as the solar crescent decreased. In fact, there is hardly a detail of the data but what we have apparently contradictory testimony in relation to it.

I am not surprised at this, whether they are merely apparent or actual contradictions. Observers have very properly given their attention to more important matters. Some have gone out with definite purposes to fulfil, others have gone to see an eclipse as a magnificent sight, and have only incidentally attended to the shadow-bands.

It is not to be expected that any person would sacrifice every other feature of so grand a phenomenon as a total eclipse of the Sun—especially if it is to be their only chance of witnessing one—in order to attend very specifically to what we have little reason to consider a matter of any particular consequence.

The modes in which the observations have been made also

* *Journal of the British Astronomical Association*, December 15, 1906.

account for some differences and create some difficulties. The observations have been made sometimes on a white sheet spread on the ground, or on a deck, at others on a whitened wall. It does not appear to me that they have been made at any time upon a screen at right angles to the direction of the Sun, except by Miss Stevens, and I confess that when definite preparations have been made to look for the bands, I am surprised at this neglect of so obvious a help to simplicity. No one would observe sun-spots or an eclipse by projection in any other way than with the screen at right angles. In order to reduce observations otherwise made, one wants a good deal of information which is not always given, and one has to do some calculation to find out what were the true dimensions or the true direction of motion. This would be avoided by placing the screen at right angles to the line of sight, and possibly the phenomenon itself would be more definite. But as the observations are it is not worth the trouble of making the necessary corrections.

The one observer who, at the last eclipse, used a screen at right angles, employed a two-inch telescope to project an image of the Sun four inches in diameter. She is one of the very few who have prepared to observe the bands with a definite purpose, and who have made serious study in advance, and I do not think she observed any bands in the image projected by the telescope, but only with the unaided eye. Indeed, I doubt the visibility of the bands by projection at all. The conclusion arrived at was apparently "that the shadow-bands are a purely local atmospheric phenomenon, and in their origin have no element of connection with the peculiar circumstances of an eclipse." This is a sufficiently definite pronouncement, and, if we receive it, no further study of the shadow-bands is necessary. But it appears to me wholly contrary to the same observer's description of the bands, for she says "they swept along with a flight that was at once rapid and orderly, there was no confusion of the wavy lines with one another, but all bore along in one and the same direction in parallel formation." Surely this parallelism and freedom from confusion is quite incompatible with the bands being purely the result of the passing of clouds driven by the winds, in varying directions, at different heights in the atmosphere, and it is also at variance with what appears to be the fact, that these bands are best seen when the air is the clearest and definition the sharpest.

The balance of evidence on the whole leads me to regard the bands as not proved to be affected by the wind to any great

extent; also that they vary from one to four inches wide, and one to ten inches apart; and that their direction is parallel to the advancing shadow, and the line of their motion at right angles to this; the utmost time of visibility, four minutes before and after totality, but mostly much less; their appearance that of gray trembling wavy bands, non-continuous, and hazy; their motion also varying in rate, and the bands themselves, as totality approaches, widening and broadening, and the whole of the phenomena reversed after totality. I freely admit, however, that much of the evidence seems incompatible with these conclusions. Where there is practical unanimity, it is impossible to aver that the bands are not, at least partially, the result of eclipse conditions.

The idea that the bands are wholly or partly diffraction phenomena is not new, for it is mentioned in the Report of the United States Naval Observatory on the Eclipse of 1869, when Dr. Curtees mentioned it in submitting another question to Dr. F. A. P. Barnard. Dr. Barnard wrote: "Your suggestion that the diffraction of the Sun's light ought to produce sensible fringes in the few moments just preceding total obscuration by the Moon is just, and your question as to whether these may not be large enough to admit of being directly observed is one which may be answered by computing the distances at which the successive bright fringes ought to be formed from the margin of the shadow." He then gives a formula for their computation, into which the distance of the Sun from the diffractory body enters, with the result that he found the first four fringes should have distances from the margin of the shadow of 46 feet, 80 feet, 103 feet, and 122 feet respectively. It will be seen that the distance between the bands rapidly diminishes, and as the calculation deals only with the first four bands, they would be almost certainly invisible so close to totality; I only mention this in connection with the idea of diffraction. But it seems to me there is no need to complicate the question by introducing the distance of the Sun into the formula. We may regard the crescent of the Sun left visible in the last few minutes as a rapidly closing slit, or band of light, of the distance of the Moon, and we can calculate the width of the fringe for any given opening in a simple manner. We have only to make the ratio of the width of the slit, or band, to the distance the numerator of a fraction of which the wavelength of light forms the denominator, or rather, the number of waves in an inch, and we get the distance of the dark fringe. Thus, if the distance is 240,000 miles and the opening one mile,

and waves 46,000 to the inch, we get $\frac{240000}{46000}$, or five inches, as the width of the fringes or distance apart. If the slit, or band, be ten miles wide, the distance of fringes would be half an inch. I make it that the 46 feet of Dr. Barnard would be the result of the crescent being reduced to 110 feet wide at the Moon's distance, but it does not alter the result if we consider the slit, or band, as being at the Sun, and, while 400 times wider, still 400 times further away.

Now, if we take this suggestion *pro tem.* (I do not say there are no difficulties about it, because I am going to mention some), I think it will be found to agree fairly with the facts of observation. It is evident that such interference fringes must be parallel with the advancing limb at the place of observation and tangential to its point of disappearance. The fringes will be, on the whole, curved, but this will not be perceptible at any station. The fringes will be unequal in width, although not much different in one or two seconds. As the slit narrows the bands must broaden and separate. They must also be indefinite as to their margins, and darkest at their central lines, and, considering the surface of the Moon is not smooth, irregularities would be manifest, and the tremulousness of the wavy lines would be caused by the heated currents of our own atmosphere breaking up the waves, in the same manner as the limb of the Sun is never free from apparent tremulousness.

Many of the discrepancies of the observations are reconcileable on this supposition: Those who saw the bands one inch apart, and those who saw them ten inches or more, will be equally correct if a short interval elapsed betwixt the observations, and the speed of movement at different stations would obviously be different according to their positions relatively to the advancing shadow. It appears to me that the speed of the bands would be neither that of the Moon in her orbit nor of the edge of the shadow, but rather that of a closing slit, and that the motion should be the reverse of this, or towards the Sun, both before and after the eclipse. But I am open to correction here.

It is open to us also to consider the question of diffraction at the limb or surface of the Moon only. I apprehend that the fact that this is a surface does not militate against the idea, because that would only soften and diffuse the rays. It is evident that the whole of the penumbra is in a condition for interference phenomena to result, only at any point where a considerable breadth of the Sun is uncovered the interference is masked by the vast quantity of undiffracted light, and the fringes would be perceptible only towards the end of the partial phase.

There are difficulties. One is that the Moon travels about thirty-five miles per minute in her orbit, and therefore three minutes before and after totality the slit would be 105 miles wide, which would reduce the fringes to a small fraction of an inch. Another difficulty is that the idea certainly does not reconcile all the observations, and I see no way of disposing of these observational discrepancies other than the usual one of theorists of declaring, that where the observations are opposed to our ideas it is so much the worse for the observations.

In my opinion the observations are not good enough to enable us to definitely settle this matter, and I hope also some one more capable will undertake to elucidate it, but I feel convinced that interference has much to do with the production of these bands.

I am sorry that attempts to photograph these shadows have hitherto been failures. A drawing of them is reproduced in Mrs. Todd's book on "Total Solar Eclipses." On this print they are so plainly shown that if it is true in its contrasts they ought to be very easy to photograph. I can only suppose the picture is intended simply as illustrative, and not as of any scientific value. She describes the bands as sometimes eight inches broad, and at others one to two inches only, and as ten or twelve inches apart, and again as two to three feet apart. And although she quotes Professor Pickering as showing that the shadow-bands originate in the terrestrial atmosphere, her own remarks rather confirm the view I have taken for she says "they lie in general parallel to the nearest edge of the shadow cone," and are "probably due to irregularities in atmospheric refraction of the slender beam of light from the waxing or waning crescent." But no explanation is offered as to how unequal refraction can produce parallel bands also parallel to the advancing limb, and this parallelism seems to me to dispose altogether of any supposition that the shadow-bands are either due to clouds or entirely the effect of our own atmosphere.

THE GYROSCOPE.

F. J. B. CORDEIRO.

FOR POPULAR ASTRONOMY.

The word gyroscope is associated in the popular mind with a small philosophical instrument or toy consisting of a miniature flywheel spinning in a ring with a vertical standard which supports one end of its axis.

In Figure 1 is pictured such an instrument. It is well known that if the flywheel is given a rapid spin by means of a string and then placed upon the supporting point as in the figure, it will not, if we let go, fall to the ground, but will support itself at a constant height. Further it makes no difference at what angle we put it upon the supporting point. It will always support itself at the initial angle and will always begin to turn slowly about the point. This of course would not be the case if it were not spinning and it also would not be the case if it were not free to turn about the point. Of this we can easily convince ourselves by opposing its turning motion with our finger when it

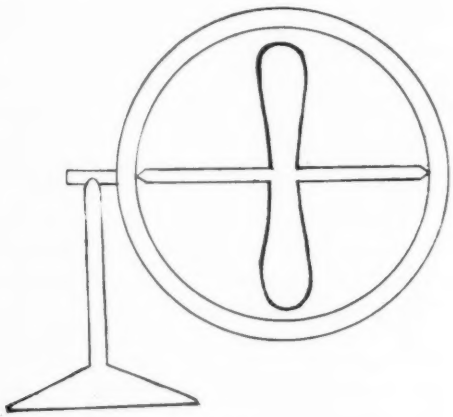


FIGURE 1

immediately falls to the ground. To the casual observer it would seem that gravity had been abolished, and it is to him a mystery. All his previous experience is here contradicted, for instead of falling as it would seem it should, it merely circles round the point at a constant height.

He will probably content himself with the reflection that while in all probability it may be capable of explanation by the higher mathematics, it is one of these things which the average person can never hope to understand. As at most it is merely a curious toy, having no possible connection with any thing of human interest, he does not trouble himself about it any further.

If however he were told that this simple toy had a most direct and far-reaching interest in the affairs of mankind, if he were assured that the principle here involved had been one of the most active factors in the history of the universe from the remote past

and would continue to exert its influence for countless ages in the future, he might wish to know something more about it, although his first attitude would be one of skepticism. If he were told that the principles here involved guided unerringly a West Indian hurricane until it demolished a Galveston, destroying thousands of human lives, or that by reason of them, London and New York many years from now would be arctic wastes, some interest might be excited. We shall show all of this and more,—but we are anticipating.

An object of interest to a large portion of mankind—the juvenile male—is a top. By a little consideration it is easily seen that this is a gyroscope. To be sure it can not spin below its point of support as the specially constructed instrument we have pictured can, but this is merely because it would come in contact with the ground. In all positions above the horizontal it is precisely similar to our gyroscope.

It is the object of this paper to explain in a simple way the principles of the gyroscope. We shall not say in a popular way, because the motions of a gyroscope cannot be explained without the aid of mathematics. But the writer believes that there is nothing in mathematics which cannot be understood by a well-ordered mind if it is presented in a suitable and interesting way. To be sure a certain foundation is necessary. There must be clear conceptions of what force and matter are. In other words the reader should have an elementary working knowledge of mechanics and he must also possess a slight knowledge of the calculus. With such a foundation it will be easy for him to follow the reasoning here presented so that he will obtain a clear grasp not only of the motions and forces at work in a top but also of the grander forces at work in the storm and in celestial mechanics. Unfortunately the subject of gyroscopic motion is presented in existing treatises on mechanics in such an abstruse and unattractive manner that it would not be possible for the average well-informed, well-educated reader to get much satisfaction from their perusal unless he were a professed mathematician. But there is no doubt but that an education or culture worthy of the name should include some knowledge of the world and universe in which we live. There is nothing in the grandest generalizations of science which can not be grasped by the simplest mind. The key to this knowledge is mathematics or crystallized truth, and there is nothing mysterious or incomprehensible about this key if it is used in the proper way.

Let us begin by first defining a gyroscope. A body having

simultaneous rotations about two different axes is a gyroscope. The instrument we have just considered and a top are evidently gyroscopes since while spinning on their axes they are at the same time turning about a vertical axis through their points of support. If the Earth at the same time that it spins about its polar axis, turns about some other axis that passes through its center, as we shall later show to be the case, it becomes a gyroscope. If a storm is revolving about its own center or axis and at the same time is being carried around the axis of the Earth, as is always the case, it is a gyroscope. A bullet revolving rapidly around its long axis and striving to keep this long axis in the line of flight is a gyroscope. In these and in many other instances a knowledge of the principles of gyroscopic motion will enable us to foresee or predict from a given initial condition what the condition of the body must be after any elapsed period of time.

For instance if a storm, which is a revolving mass of air, has a given position and intensity at a given time we can calculate by this knowledge to what new position it will have moved after a given lapse of time. The paths traced by storms over the surface of the Earth are exceedingly regular and as obedient to the laws governing their motions as are the planets. The Earth itself is, as we shall see, a giant gyroscope, and in obedience to these laws is continually tipping its axis to the plane of the ecliptic. We can easily calculate the time when it will have tipped over so far as to plunge all regions lying in higher latitudes into a condition of arctic ice, as it has already done several times in the past. We can further as easily calculate the times back when these successive 'Glacial Epochs,' have occurred. It is the hope of the author that the time will come when such knowledge will be considered essential in every well-rounded scheme of education, when, in place of the various questionable branches in which educational energies are dissipated, no man can be considered to possess a truly broad or liberal culture who is ignorant of the calculus.

The love of truth engendered by such studies can not fail to react in making better citizens, and it is a question whether general public indifference to morality can not be directly traced to faulty systems of education.

We shall begin by considering the gyroscope in its simplest form, such as a top under the influence of no forces.

In Figure 2 let us suppose that GI is a heavy disk capable of spinning about the axis OG which passes through the center G. Further

the axis WOG is capable of turning about the point O, which is fixed in any direction. We can abolish gravity by fixing a counterbalancing weight at the other end of the axis, so that the system will move exactly as if gravity did not exist. We shall first give the wheel G a spin in such a direction that the point I on the disk is coming up through the page. Now let us hit the

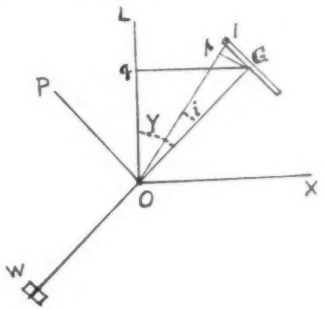


FIGURE 2

system a smart tap so that it will tend to revolve about the point O directly downwards through the page, i. e., it will start to revolve about the axis OP which is perpendicular to OG. It is now left to itself, no further forces acting upon it, and the problem is to determine the subsequent motion.

We have here a double rotation. The points on the disk to the left of G are coming up through the page and the whole system is moving bodily downward through the page. Now there must be some point to the left of G where these two opposite velocities will exactly counterbalance each other. Let us suppose that the point I on this disk is the particular point. For the first instant of motion, therefore, the system will move as if it had only a simple rotation about the axis OI, which we shall call the instantaneous axis. Now let us suppose that the disk is spinning with a constant angular velocity ω, and that the blow imparted to the system an angular velocity μ about the axis OP. Since the point I remains for the first instant in the page, and does not move, we have

$$GI.\ \omega = OG.\ \mu$$

We do not say that the system will continue to rotate about the axis OI, but only that at the first instant it will start to do so. Now the moment of momentum of the disk about the axis OG is $Mk^2\omega$, where M represents the mass, and k the radius of gyra-

tion. This simply means that the *quantity* of motion in the disk would be the same if all its mass were concentrated into a thin ring at the distance k from the center G, and the moment of this quantity about the axis OG is found by multiplying it by k. Now the moment of momentum about an axis is a quantity which can be resolved into a component about any other axis by multiplying it by the cosine of the angle between the two axes.

Let us draw through the point O two lines OX and OL perpendicular to each other. Drop a perpendicular from G to q on OL, and call the angles GOI and GOL, ι and γ respectively. Let the angular velocity of G about OL be Ω, and about OI, ω_1.

Now the point G is passing through the page with a velocity OG sin ι ω_1, and the disk is at the same time rotating about this point G, its center of gravity, with angular velocity ω. Therefore its moment of momentum about the line OX is

$$M.OG^2.\ \sin \iota \cos \gamma\ \omega_1 - Mk^2\omega \sin \gamma.$$

The first term represents the moment of momentum of the mass, supposed to be concentrated at its center of gravity, about the axis OX, and the second term is the component about this axis due to the spin. They are given opposite signs because they rotate in opposite directions about OX.

Now it is clear that the moment of momentum which we have just found about OX will vary as we change the direction of this line.

But we can always find one direction, and one only, in the plane GOI, such that this quantity will vanish. We have only to choose the angle γ so that the two partial moments we have found shall be equal. In other words to solve the equation

$$M.\ \overline{OG}^2.\ \cos \gamma.\ \sin \iota.\ \omega_1 = Mk^2 \sin \gamma.\ \omega.$$

We see then that there will be absolutely no turning movement about such a line OX–in other words the point G will start off in a direction parallel to the plane drawn through OX and perpendicular to OL. But once started in this direction, since no further forces act upon it, it must forever afterwards move parallel to this plane. Since the point G must remain at a constant height above this plane, it follows that the axis OG will maintain a constant angle with the line OL, in fact describe a cone about it. This line OL we shall call the invariable line. It is easily seen that the instantaneous axis OI will always remain in the plane GOL, so that the subsequent motion of our gyroscope is completely determined. It would be the same as if we imagined a cone GOI fixed to the gyroscope rolling upon a cone

GOL fixed in space. This is the motion of a gyroscope started off with an initial impulse and then left to move without the action of any further forces. The axis OG will continue revolving about the invariable line OL at a constant angle γ and with a constant angular velocity Ω. The system as a whole will at any instant be turning about an instantaneous axis OI in the plane GOL and this axis OI will make a constant angle ι with the axis OG.

Let us denote the moment of momentum of the disk about the axis OP, or M. $\overline{OG}^2$, by A, and its moment of momentum about the axis OG by C. We have found then that

$$A \sin \iota \cos \gamma . \quad \omega_1 = C \omega_1 \sin \gamma .$$

Now $\omega = \omega_1 \cos \iota \quad \therefore A \tan \iota = C \tan \gamma .$

Hence knowing the mass of the gyroscope and the initial velocities of the spin and the turn, the whole subsequent motion of the system is determined.

Now, instead of representing the motion as the rolling of one cone upon another, we could equally well suppose a surface of revolution about the axis OG to be rigidly attached to the gyroscope and by making such a surface roll upon a plane perpendicular to OL and tangent to the surface, the motion would be equally well represented.

Let us now draw the line GL perpendicular to OG. This line will evidently describe a cone tangent to a sphere drawn about O with the radius OG.

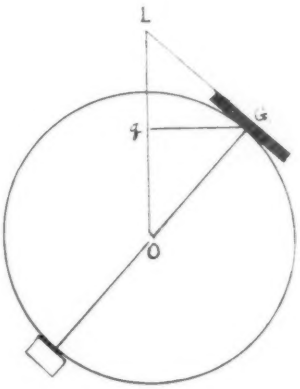


FIGURE 3

The path of G will be a circle upon this sphere. Since the gyroscope is revolving at a constant rate and distance from the point L, it follows that the centrifugal and centripetal forces

directed away from and to this point must be equal and exactly balance each other. Now by elementary mechanics we know that the centrifugal force directed along the line LG, tending to throw G away from L as it revolves about it, is

$$M.OG \sin\gamma . \cos\gamma . \Omega^2$$

where Ω is, as before, the angular velocity about the point q—the perpendicular from G on the line OL. It follows therefore that the result of turning a spinning body is to produce an acceleration always at right angles to its path. Further this normal accelerative force will be equal to

$$M.OG \sin\gamma \cos\gamma \Omega^2.$$

But since

$$A \tan\epsilon = C \tan\gamma \quad \text{and} \quad \Omega \sin\gamma = \omega \tan\epsilon$$

we may write

$$M.OG \sin\gamma \cos\gamma \Omega^2 = \frac{M}{OG} k^2 \omega \sin\gamma \Omega.$$

But $\Omega \sin\gamma$ is the angular velocity with which the center G is turning in its path about the fixed point O. In other words, at any instant there is always a force acting upon it directed at right angles to its plane of motion, and equal to the product of its mass into the square of its radius of gyration, into the angular velocity of the spin, into the angular velocity with which it is turning in its path about its fixed point, divided by the distance of its center of gravity from the fixed point. This is the fundamental property of the gyroscope from which all others can be easily derived. We shall now be able to understand all the peculiarities of motion of such a body under all circumstances.

To recapitulate, we have found *this* to be the fundamental property of the gyroscope, viz., that if we turn a spinning disk about a fixed point in its axis in any direction (or plane), there will immediately be set up a force pulling upon it in a direction at right angles to the direction in which it is moving. If the disk were not spinning, its path would be in the direction of the force moving it, but the spinning sets up a force at right angles to its path at any instant. We have seen that if we start it off in any direction and then allow no further outside forces to act upon it, it will continue to circle about a fixed line OL and that the natural deflecting force is continually pulling it away from the great circle it would otherwise describe on the sphere. A small spin will only deflect it slightly, so that it will describe a circle nearly as large as the great circle it otherwise would, and tangent to the great circle at the point of starting.

From the equation $A \tan\epsilon = C \tan\gamma$, we see that with a very

rapid spin, ι and γ become very small, and therefore the result of striking a heavy blow on a very rapidly spinning gyroscope would be to cause it to oscillate rapidly about a very small circle passing through its initial position. Here we find to a certain extent a confirmation of the popular idea that a gyroscope tends to preserve its plane of rotation. But a gyroscope has no tendency to preserve its plane of rotation. It changes its plane as readily as if it were not rotating, only in a different way.

It is rather startling to find that with an infinitely great spin we might strike our gyroscope a heavy blow with a hammer and yet be unable to move it. But this is merely an extreme case, and the proper way to regard it is that a gyroscope offers no resistance to a change of plane, but only changes the direction of the forces acting upon it.

We come now to consider the result of a constant and constantly directed force, such as gravity, upon a spinning disk.

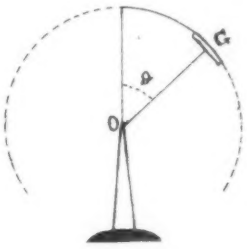


FIGURE 4

Let θ be the angle which the axis OG makes at any instant with the opposite direction to gravity and ψ the angle which a vertical plane through O and G makes with the initial vertical plane. The angles θ and ψ express the latitude and longitude of the point G at any instant. Let us represent the distance OG by l and the angular velocities and angular accelerations by $\dot{\theta}, \dot{\psi}$ and $\ddot{\theta}, \ddot{\psi}$, respectively.

From the fundamental principle of the gyroscope we can write at once

$$l\ddot{\psi} = \frac{k^2 \omega \dot{\theta}}{l} \quad (1) \text{ and } g \sin\theta - l\ddot{\theta} = \frac{k^2 \omega}{l} \sin\theta \dot{\psi} \quad (2)$$

Integrating (1) we have

$$l^2 \dot{\psi} = k^2 \omega \quad (\theta - \theta_0) \quad (3)$$

where θ_0 is the initial angle.

Substituting (3) in (2) and multiplying by θ, we have

$$g \sin\theta . \dot{\theta} - l\dot{\theta}\ddot{\theta} = \frac{k^4 \omega^2}{l^3} \sin\theta \quad (\theta - \theta_0) \quad \dot{\theta} \quad (4)$$

Integrating (4),

$$\frac{l^2\dot{\theta}^2}{2} = gl\ (\cos\theta_o - \cos\theta) + \frac{k^4\omega^2}{l^2}\left[\cos\theta(\theta-\theta_o) - (\sin\theta - \sin\theta_o)\right] \quad (5)$$

If we make $\dot{\theta}$ equal to zero, it is clear that only one value of θ, outside of the initial value of θ_o, will satisfy the equation. The vertical movement of the gyroscope is therefore confined between these limiting values. We already then know a good deal of what the subsequent motion will be. It begins at first to fall vertically, but soon a horizontal motion is superadded. By the principle of energy the total velocity at any instant will be proportional to the square root of the vertical drop, but this is distributed between the vertical and horizontal components in respectively decreasing and increasing proportions, until finally the motion is all horizontal. After this it begins to rise until at the original level it comes to rest again, and the process is repeated over and over again.

Let us see if we can discover what kind of a path the point G traces. In order to simplify matters we shall consider only a very small portion of the sphere, so that we can consider this area as plane and $l\theta$ and $l\psi$ as rectangular coördinates.

In this small area we can consider the moment of gravity as constant and equal to lg sin α. Our equations of motion assume the following simplified forms:

$$l\ddot{\psi} = \frac{k\,\omega\,\dot{\theta}}{l} \quad (6) \text{ and } g\sin\alpha - l\ddot{\theta} = \frac{k^2\omega}{l}\ \dot{\psi} \quad (7)$$

Integrating, we have

$$l\dot{\psi} = \frac{k^2\omega}{l}\ \theta \quad (8) \quad \text{and } g\sin\alpha\, t - l\ \dot{\theta} = \frac{k^2\omega}{l}\ \psi \quad (9)$$

Since we assume the origin of coördinates in this plane where the body would come to rest under the conditions of motion.

Now if we write the equations

$$l\psi = \frac{g\sin\alpha}{K^2}\ (Kt - \sin Kt) \quad (10) \qquad \text{and}$$

$$l\theta = \frac{g\sin\alpha}{K^2}\ (1 - \cos Kt) \quad (11)$$

where $K = \frac{k^2\omega}{l^2}$, we easily see by differentiating that they are the integrals of equations (8) and (9) respectively.

Now equations (10) and (11) represent a cycloid with its base horizontal, convex downwards, and having a cusp at the origin of coördinates. Of course the point G can not leave the surface of the sphere, but in the small part of this sphere which we can consider included in our plane, it traces a part of a cycloid

such as we have described drawn in the plane. Every portion of the path therefore is a portion of a cycloid in a plane tangent to that particular part of the path. It follows therefore that the point G in tracing its path upon the sphere moves in the quickest time possible under the conditions from one point in the path to another. The equations of a cycloid are usually written

$$\psi = a \quad (\phi - \sin \phi) \quad \text{and } y = a \quad (1 - \cos \phi)$$

where a is the radius of the generating circle and ϕ is the angle which the radius at any time makes with its initial position. We see then that the radius of our generating circle, and therefore the corresponding cycloid, is quite large if ω be small. But if ω be large the radius of the generating circle becomes very minute. With a rapid spin, therefore, it would be possible to trace a large number of our cycloids even in the small area to which we have restricted ourselves. The radius of our generating circle is then

$$g \frac{\sin \alpha}{K^2} \quad \text{or} \quad g \frac{\sin \alpha . l^4}{k^4 \omega^2}.$$

The time of falling through one of these cycloids is found by making Kt equal to 2π

$$\text{and therefore is } \frac{2\pi}{K} \quad \text{or} \quad \frac{2\pi l^2}{k^2 \omega}$$

We see then that the time of one of these vibrations is independent of the actuating force.

We have now a complete knowledge of the motion of our gyroscope. If the spin is small, there is a considerable rise and fall which is easily observed. It here traces out a path which we might call a spherical cycloid, because every element is part of a definite cycloid which could be drawn upon the plane tangent to the sphere at that element. With a very rapid spin, the rise and fall can not be observed by the eye, though the ear can take up the humming caused by the minute vibrations. The motion here is the same as if the extremity of the axis were attached to the circumference of a very small wheel and this wheel were rolled along the under side of a parallel of latitude. The axis therefore carves out in space a cycloidally fluted cone with the cusps upwards. If at the instant of starting we could give the gyroscope an initial horizontal velocity, such that its upward deflecting force was exactly equal to that of gravity, then there would be no rise and fall, and the axis would describe a smooth cone. If the spinning ceases the cycloid degenerates into a great vertical circle and the motion becomes simply that of a pendulum passing at every swing through the point vertically under the

point of support. But it will never pass through this point as long as it possesses the slightest spin.

We see now clearly why the gyroscope supports itself. As soon as it acquires a vertical angular velocity downwards, normal deflecting forces are set up which pull it away from this direction, and the direction of its path being continually changed, it is eventually pulled up to the level from which it originally started. This is repeated in rapid oscillations over and over again. Again if we constrained the gyroscope to move in a vertical plane, as by placing the extremity of its axis in a vertical groove, it would fall like a pendulum exactly as if it were not spinning, provided we do not take the friction caused by the horizontal pressure into account, for the normal deflecting force only arises from an actual velocity, and if we prevent this velocity from coming into actuality, it can cause no deflecting force.

We have seen that the fundamental property of a gyroscope is that $\frac{Mk^2 \omega \dot{\theta}}{OG} = M f$ where f represents an acceleration perpendicular to the plane $\dot{\theta}$. This means that the normal turning moment about the point O is $Mk^2 \omega \dot{\theta}$.

Now if we turn the gyroscope about its own center of gravity, OG will become zero and f mathematically infinite. But the product f.OG still remains finite and is the turning moment of a couple exerted in a plane perpendicular to the plane of $\dot{\theta}$ and passing through the axis. This moment is numerically equal to $Mk^2\omega\dot{\theta}$.

Numerous applications of the phenomena exhibited by gyroscopes have been attempted with more or less success.

The well-known Howell torpedo consists of a heavy flywheel G, Figure 5, spinning in a vertical plane with its horizontal transverse axis fixed to the shell of the torpedo. The stored up

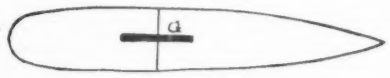


FIGURE 5

energy of rotation is used as the motive power and the center of buoyancy is so placed that the torpedo always tends to right itself. If at any time while running on an even keel its direction should become changed horizontally, it is evident that it will roll over on its fore and aft axis. A heavy pendulum within the torpedo is thus caused to swing over and actuate two vertical rudders in such a direction as to bring the torpedo back to its

course. It is thus seen that any deviation will be more or less corrected, though an exact restitution will not generally be effected. Further, whatever currents carry away the torpedo parallel to itself cannot be corrected.

In general when we apply a force to a gyroscope in a certain direction for a certain length of time and then apply an equal force in the opposite direction for an equal length of time, we shall bring it back to its exact position at starting. This principle has been successfully applied to torpedoes in what is known as the Obry device. A change of direction in the torpedo causes a deflection in a small gyroscope contained within the torpedo, which by suitable mechanism throws the rudders over so that they bring the torpedo back to its course. The process of coming back to the original course, on the other hand, throws the rudders back to the original position. It is easily seen that by suitable arrangements such a device may be made self-setting, so that the torpedo may run a certain definite distance on its original course and then be made to turn a pre-determined angle. In this manner torpedoes are launched at a certain angle with the course of the ship, run off a short distance and then move forward parallel to the ship.

Since every body on the surface of the Earth possesses a constant, though small, angular velocity about the Earth's axis, attempts have been made to utilize the deflective force set up by this angular velocity in gyroscopes, as a substitute for the Earth's magnetic field in determining the direction of the pole. This would have a marked advantage over the compass because this deflective force is always in a plane passing through the pole, while the magnetic force is only approximately so. At some places it is not even approximately so. Further it is variable at the same place, besides varying in different places. On board ship there are disturbing actions due to the proximity of iron which makes the use of the compass difficult. The writer knows personally of two such attempts made twenty years ago, and only recently a German experimenter has sought to effect the same end by an elaborate apparatus. (See *Physikalische Zeitschrift*, for August, 1906).

Let us examine the conditions surrounding such a problem. In the first place the angular velocity of the Earth is very small, so that to magnify its normal or northward deflecting force a very rapid spin will have to be imparted to our gyroscope. This spin can easily be made so great that it will develop a considerable northerly force. But we have seen that while a gyroscope will

oscillate about a constantly directed force (gravity for instance) it can never bring its axis into coincidence with this direction.

The gyroscopic pendulum, as we have seen, can never point directly downwards. Consequently such an instrument can never give us direct information of the direction we are seeking. It can only give us indirect information by describing a cone about the required direction. Let us see what time it will take to make a complete circuit about this direction. We have seen that it progresses a distance equal to the circumference of the generating circle, or $\frac{2\pi g \sin \alpha}{K^2}$ in the time $\frac{2\pi}{K}$. It will require therefore a time equal to $\frac{2\pi k^2 \omega}{g l}$. In other words if the spin is great the time for a complete circuit will be very great. But if the spin is small, then we lose directive force, so that such an instrument seems impracticable.

It might be possible to construct an instrument as in Figure 6, where a gyroscope is pivoted at a point O in its axis and a long pointer OP is constrained to move in a groove in the arc AP. By moving the plane of the arc about the vertical standard, it would

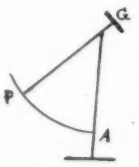


FIGURE 6

be found that the position of greatest inclination coincided with the meridian. But such an instrument would be rather insensitive for several degrees on each side of the meridian. The maximum inclination would be proportional to the cosine of the latitude, so that it would give better indications in low latitudes.

A bullet in its flight describes approximately a parabola. At its exit from the gun it is rotating rapidly about its long axis,

FIGURE 7

and this axis is inclined to the horizon at the angle of elevation of the gun. As the direction of the path changes, the resistance

of the air causes it to turn so that it shall present a minimum surface; in other words it strives to keep its long axis in the line of flight. The result of this turning of a gyroscopic bullet is that a part of the turning moment is expended at right angles to its plane of flight. Consequently such a bullet will have a drift to the right or to the left according to the direction of the rifling. It seems odd that quite recently various explanations have been attempted for the "Drift" none of them being the true one.

In 1855 Foucault demonstrated for the first time the rotation of the Earth on its axis by the deflection of a gyroscope. It had not been realized nor is it yet generally realized that this rotation had long been and is being continually demonstrated by the movement of another kind of gyroscopes, viz., storms.

But before we take up the subject of storms a few preliminary considerations will be necessary.

(To be Concluded.)

21 Oberlin Street,
Worcester, Mass.

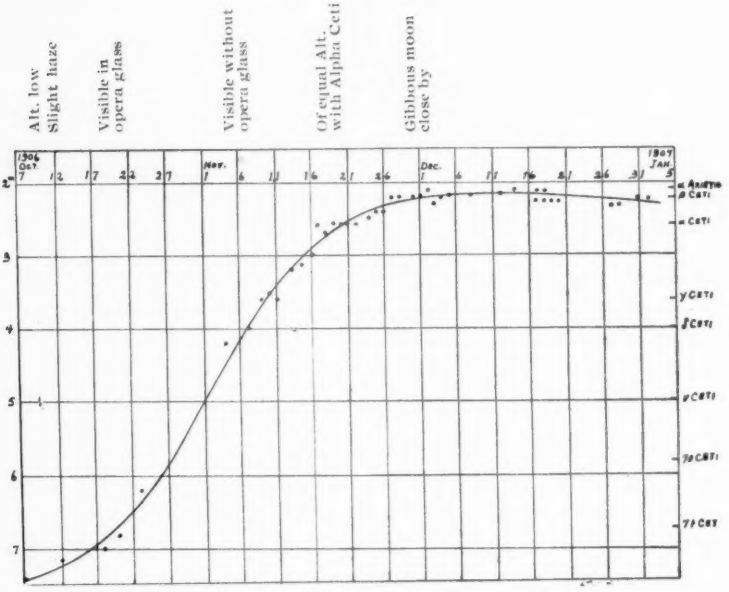
LIGHT CURVES OF MIRA AND W LYRÆ.

ROSE O'HALLORAN.

For Popular Astronomy.

Whether the variability of Mira (*o* Ceti) be the result of collision, tidal effects, or innate explosiveness, the recent maximum indicates that the hidden cause has worked with more than its ordinary force. From the dimness of ninth magnitude in September it rose to second magnitude in December, a degree of lustre not attained in many years past. Its advance was uneven, as usual, and though the sublime heights of light-splitting skill were not scaled in the following estimates of increase, the accompanying light curve represents fairly well the ascent and maximum.

As may be seen, the rise, at first gradual, was rapid between the twentieth and twenty-third of October when of nearly sixth magnitude. During the twelve following days when clouds and moonlight hindered observation, it advanced two magnitudes; and then including a slight cessation of increase for a few days about the twentieth of November, twenty-three days were occupied in attaining the next two magnitudes, namely from 4.2 to 2.2. On December the second, fourteenth, seventeenth, and eighteenth it equalled a Arietis, when both stars were near the meridian,



LIGHT CURVE OF MIRA (*o* CETI) OCT. 7 TO JAN. 3

but on the last two days seemed two steps dimmer at an earlier hour, probably on account of a lower altitude. If of the same high altitude as a Arietis, it might have equalled that star more steadily or even have surpassed it.

A slight decline was indicated by the few observations afterwards obtainable. Having observed the variable during the last nine maxima that occurred unobscured by sunlight, the following list will convey an idea of the range that is usual as to period and light.

	Time of Maxima				Magnitude.
1895	between mid. of Feb.	and	mid. of March		About 3.8
1896	" Jan. 21	and	Feb. 21		" 3.8
1896-7	" Dec. 21	and	Jan. 1		" 3.8
1897	" Nov 10	and	Dec. 12		" 3.4
1898	" Sept. 30	and	Oct. 5		" 2.6
1899	" Sept. 5	and	Oct. 1		" 4.0
1905	" Feb. 6	and	March 8		" 3.5
1906	" Jan.				4.0

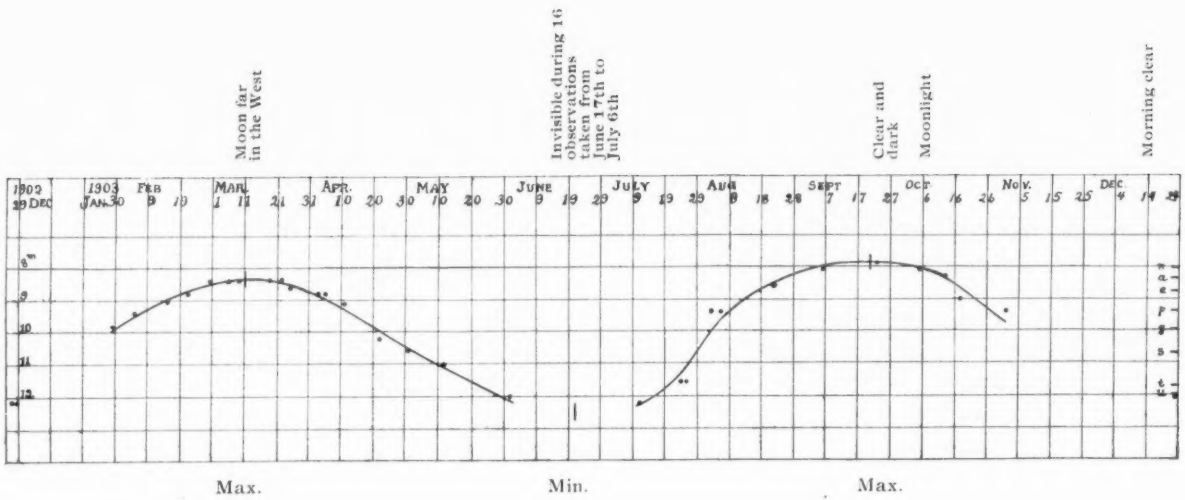
As Mira is the only variable of long period that gains sufficient light for a detailed study of its spectrum, the recent high range is of especial interest to the spectroscopist. This is but the second opportunity that has occurred since recent advances in light

analyses both theoretic and instrumental. In 1898, Director Campbell of the Lick Observatory, made important discoveries as to the radial velocity of this star, with one of the most effective appliances for such work now in use. It was found that some bright lines of hydrogen indicated a slow motion of recession, while simultaneously, dark lines of the same substance revealed rapid motion in the same direction. According to the researches of Zeeman, a German physicist, a strongly magnetic field interferes with the usual position of spectral lines. The transient glow of the variable waned however before extended investigation was possible, and the seven succeeding maxima were of too low a range for the study of such complexities.

All observatories with facilities for spectroscopic research have now been favored with a bright and prolonged season of increase, and if shifting lines have another significance than that discovered by Doppler, magnetism and electricity beyond the Earth may eventually become something more than a resourceful hypothesis. In his annual report of the Lick Observatory for 1905, the Director called attention to the necessity of a reflector, larger than any now in use, for the study of variable spectra at maxima and minima; and in a recent lecture Professor Pickering urges the construction of such an instrument for international requirements and use. Should these suggestions from high sources be complied with, much light will be won from stars of fitful gleam and other cosmical objects that now elude research.

W Lyræ, another long period variable, never attains the lustre of Mira, but it is an interesting object for telescopic observation as its phases are not monotonously punctual. They range from eighth to less than twelfth magnitude, and the entire cycle is completed in about 200 days. In this brief time it shows the characteristics of its class, increase being more rapid than decline, its halt most prolonged in the dim stage, and the range at maxima not always equal. As D. M. + 36° 3066 it was not known as a variable until Thomas D. Anderson, the famous discoverer of novæ, noted its presence near Kappa Lyrae in January 1896. It is not in Chandler's Third Catalogue but provisional notation and elements appear in A. J. 514, page 80.

Having commenced to observe the star in October 1899, I obtained only 240 observations during the seven following years, as the fair edifices of San Francisco in the past, towering in all directions, were sometimes prejudicial to star-gazing. Five series of these observations included complete maxima, and portions of five maxima were also observed, though the crest of the in-



LIGHT CURVE OF W LYRÆ (D. M. + 36° 3066) 1902-3

crease could not be ascertained in the latter cases. As the four-inch refractor used does not penetrate much beyond twelfth magnitude, the minima could be only known to have occurred sometime during the weeks of invisibility. With this restriction, portions of ten minima either before or after complete invisibility were seen, and sometimes on both sides of that stage.

The accompanying light curves, founded merely on my own observations—which however were carefully taken under favorable conditions—convey an idea of the average differences noticeable in maxima. Occasional anomalies occur, as when in 1905 the variable rose from twelfth magnitude or less to eighth between February the sixth and May the fifth, a period of 89 days; and from May the ninth to July the sixteenth, a period of 68 days decreased to twelfth magnitude again; while in 1906, the minimum from twelfth magnitude down to invisibility and up to twelfth lasted 59 days. Judging from the seeming crests of the two light curves, which would include a complete cycle, these depicted maxima were only 194 days apart, but both the preceding and the following cycle had a duration several days longer.

The culmination of a maximum on July the twelfth 1901, and of another on April the eleventh 1904, both of which were under favorable observation in ascent and descent, included five cycles. The intervening maxima and minima were also more or less recorded, and as the series included 1004 days an average allotment for each of the five cycles would be somewhat over 200 days. If the interval be extended to the fifth of June, 1906, including nine cycles, eight maxima of which were more or less observed, 198 days is the result obtained. Periods close to these were assigned to the star many years ago by skilled observers.

Its position is R. A. $18^h\ 11^m\ 28^s + 36°\ 38'$, and its dimmest phase can be viewed in large telescopes. At maximum, on clear dark nights, as it gleams among a group of telescopic stars scattered around it in a somewhat triangular outline, its yellow tint may be noticeable when it attains to eighth magnitude, which occurs about as frequently as the lesser maximum of 8.4. In the course of ascent and descent some faint fluctuations have been suspected. The magnitudes of the adjacent comparison stars were published in *Popular Astronomy* for October, 1897. As to my vision the star called 'a' comes nearer to 'n' than five steps, and seems farther from 'e' than two steps. I have placed it midway between them on the margin of the diagram; and 't' I advanced two steps, or to 11.8 magnitude, but otherwise the values given in the above named number are unaltered.

San Francisco,
January 4, 1907.

ROTATION OF GIACOBINI'S COMET *c* 1905.*

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

In the Harvard Annals XXXII 271 evidence is brought forward to show that the tail of Swift's comet, 1892 I, exhibited a rotation about its axis in a period of about four days. Dunlop, *Edin. Jour. of Science*, 1827, had come to a similar conclusion regarding the comet of 1825 IV, although the period that he had fixed was very short, being less than 20^h. Observations of Halley's comet 1835 by Bessel indicated a rotation in rather less than five days. The theoretical necessity that such a rotation should exist is shown in the above mentioned paper in the Annals, and need not be demonstrated again in this place.

At the recent meeting of the *Astrophysical Society*, a very interesting series of photographs of Giacobini's comet was shown by Professor Barnard, and after the meeting he kindly loaned them to the writer for further study.

	Date	Tail		Date	Tail		Date	Tail
Dec.	25	*n*	Dec.	30	*b*	Jan.	4	*n*
	26	—		31	—		5	*m*
	27	—	Jan.	1	—		6	—
	28	—		2	—		7	*b*
	29	*b*		3	—		8	*m*

A casual examination shows at once that they can be divided into two main classes, in one of which the tail is narrow, and in the other broad. We can imagine it to be shaped something like a sword which is alternately presenting its edges and its flat sides towards us.

The rotation was rather slow, and as the comet was only visible for a short time, the photographs extending through a range of but fifteen days, the evidence is not as complete as it was in the case of Swift's comet. Nevertheless, an inspection of the table shows pretty clearly what its period of rotation must have been. In the second column an *n* indicates that the tail was narrow, a *b* that it was broad, and an *m* that it was medium. On December 29 the breadth was more clearly marked than on the next night. It was broad again upon January 7. This would correspond to an interval of nine days. Similarly between December 25 and January 4, when the tail was narrow, the interval was ten days. The record is unfortunately rather incomplete, but the interval of nine days seems the better established of the two. The period of rotation must be twice this, or eighteen days.

* See Frontispiece.

It is hoped that future comets presenting tails will be photographed as frequently as possible at all those observatories possessing suitable appliances, in order that more complete records may be obtained of this interesting phenomenon. Indeed, it is not impossible that a study of the electrical forces radiated within the angular area covered by the comet as seen from the Sun might give us our first clew to the masses of these bodies,—a quantity of which we are at the present moment absolutely ignorant.

Cambridge, Mass.
January 14, 1907.

CONCERNING THE CONSTITUTION OF THE ETHER.

LUIGI D'AURIA.

FOR POPULAR ASTRONOMY.

At the Washington meeting of the American Association for the Advancement of Science, December 31, 1902. I read a paper on "A relation between the mean speed of stellar motion and the velocity of wave propagation in a universal gaseous medium bearing upon the nature of the ether," in which paper it was shown first that the distribution of density in a large sphere of gas in equilibrium of temperature, subject to the Newtonian law of attraction, would follow the law of the inverse square of the distance from the center of the sphere; and then, on the supposition that the stellar universe is a finite system, and that the stars are moving in a large sphere of gas, gravitational and in equilibrium of temperature, the conclusion was reached that the mean square speed of the particles of the gas, could not be much greater than the mean speed of stellar motion. (See *Journal of the Franklin Institute*, March 1903, and *Popular Astronomy*, May, 1903). Since this latter speed is about twenty miles per second, and since the velocity of wave propagation in a gaseous medium is considerably less than the mean square speed of its particles, the above conclusion shows that the ether cannot be a gas subject to the law of universal gravitation.

While I was preparing my paper for publication, I found that the late Professor De Volson Wood, in an article published in the *Philosophical Magazine* for November, 1885, under the title: "The Luminiferous Ether," had considered the ether as a gravitational gas, and on examining this article I found that the author had reached the conclusion that such an ether would have uni-

form density. Having satisfied myself that the analysis of my problem was correct, I proceeded to examine Professor Wood's analysis, and found that his conclusion was due to an unfortunate error which I preferred not to mention in my paper. That this error should have remained unnoticed for more than twenty years in a paper which has attracted so much attention and which has been kept before the public, up to the present time, in the form of an Appendix to Wood's Thermodynamics, may seem rather surprising. But on the other hand, any one who has read Professor Wood's paper must have been impressed by the masterly way in which he has handled the subject, showing a rare acquaintance with thermodynamic principles and with the kinetic theory of gases, and it is not surprising, therefore, to find Professor Wood's hypothesis of the ether recently endorsed by the well-known author, J. Ellard Gore, F. R. S., etc., in his excellent work, "Studies in Astronomy," dealing with the best views advanced in Astronomical Science.

This author, after calling attention to Young's conception of the ether as an elastic solid, page 317, remarks: "Now as our finite minds cannot grasp the idea of a solid which is impalpable to the touch and invisible to our sight—as the ether evidently is—any theory which would relieve us from the necessity of imagining, or trying to imagine, such an anomalous substance should be very acceptable to our finite intelligence. Such a theory was advanced a few years ago by Professor De Volson Wood, and as his views, which are very carefully worked out, seem to be mathematically sound, some account of his hypothesis of the constitution of the ether may prove of interest to the general reader."

Continuing, the same author says: "Professor Wood assumes that the ether is gaseous in its nature, and consequently, molecular in structure, a conception which seems more probable than the hypothesis which ascribes to it the properties of a solid."

Professor Wood states his problem as follows:

"Admitting that the ether is subject to attraction according to the Newtonian law, and to compression according to the law of Mariotte, we propose to find *the relation between the density of the ether at the surface of an attracting sphere and that at any other point in space*, providing that the sphere be cold and the only attracting body, and the gas considered the only one involved."

Here is his analysis:

Let δ_0, e_0, w_0, be respectively the density, elasticity, and weight

of a unit of the medium whether ether, air or any other gas at the surface of the sphere: δ, e, w, the corresponding quantities at a distance z from the surface of the sphere; r the radius of the sphere, g_o the acceleration due to gravity at its surface, and g that at distance r + z from the center of the sphere. Then

$$\frac{\delta}{\delta_o} = \frac{e}{e_o} = \frac{w}{g} \div \frac{w_o}{g_o},$$

and

$$g = g_o \frac{r^2}{(r+z)^2};$$

$$e = \frac{e_o}{w_o} \frac{g_o}{g} w = \frac{e_o}{w_o} \frac{(r+z)^2}{r^2} w.$$

But

$$de = -w\, d\, z = -g\, \delta\, d\, z,$$

$$\frac{de}{e} = -\frac{g_o \delta_o}{e_o} \cdot \frac{r^2}{(r+z)^2} dz.$$

Integrating between e and e_o, z and o, we have

$$e = e_o \epsilon^{\frac{-g_o \delta_o}{e_o} \cdot \frac{r z}{r+z}}$$

$$\delta = \delta_o \epsilon^{\frac{-g_o \delta_o}{e_o} \cdot \frac{r z}{r+z}}$$

The last two equations are applied by Professor Wood to the case of the Sun considered as the only attracting body with the remarkable result that at a very great, or infinite distance from the Sun the elasticity and density of the ether would be equal to the elasticity and density of the ether at the Sun's surface multiplied by the 995,000 root of ϵ, which is sensibly equal to unity. This is the same as to say that in a gravitational gaseous ether in equilibrium of temperature the tension and density may be considered uniform throughout space. When Professor Wood reached this conclusion he exclaimed: "Such has been our conception of it and it is an agreeable surprise to find it so fully confirmed by analysis."

It will be observed that putting r = o, in Professor Wood's last two equations, that is, if we eliminate the central attracting sphere, leaving the ether alone in space, we find $e = e_o$ and $\delta = \delta_o$, showing that in such case the tension and density of the gaseous gravitational ether would be absolutely uniform throughout its mass. I found, on the contrary, as stated at the beginning of this paper, that for such an ether the density (and, of course, the tension) would vary inversely with the square of the distance

from the center of the sphere of ether, and I believe this conclusion to be absolutely sound.

Let us examine now the analysis of Professor Wood given above. It will be observed that in putting

$$g = g_o \frac{r^2}{(r+z)^2},$$

Professor Wood neglects the attraction due to the mass of the ether surrounding the attracting sphere out to the distance z. It is true that the influence of such an attraction upon the value of g at a distance comparable to planetary distances when the central attracting sphere is the Sun, can be easily neglected, but this is not the case when the value of z becomes as large as the radius of the visible universe, for a mass of ether having such a radius is comparable to the mass of the whole stellar universe, a fact which was pointed out in my paper on "Stellar Dynamics," read May 13, 1897, before the American Philosophical Society of Philadelphia, and published October 1897, in the Journal of the Franklin Institute.

In order to find the proper expression for g in Professor Wood's problem, let δ_1, be the mean density of the attracting sphere, and δ_2 the mean density of the mass of ether surrounding this sphere out to the distance z. Then

$$g : g_o = \frac{\frac{4}{3}\pi r^3\delta_1 + \left[\frac{4}{3}\pi(r+z)^3 - \frac{4}{3}\pi r^3\right]\delta_2}{(r+z)^2} : \frac{\frac{4}{3}\pi r^3\delta_1}{r^2},$$

and

$$g = g_o \frac{r^2}{(r+z)^2}\left\{1 + \left[\left(\frac{r+z}{z}\right)^3 - 1\right]\frac{\delta_2}{\delta_1}\right\}$$

Putting this value in the expression for de above, we get

$$\frac{de}{e} = -\frac{g_o\,\delta_o}{e_o}\frac{r^2}{(r+z)^2}\left\{1 + \left[\left(\frac{r+z}{r}\right)^3 - 1\right]\frac{\delta_2}{\delta_1}\right\} dz,$$

an expression which cannot be integrated unless we know how to express δ_2 in function of z. This would really amount to a knowledge of the law of variation of density in the mass of ether in question, which was the object of Professor Wood's problem. Now, as the above equation becomes indentical with the corresponding one in Professsor Wood's analysis when we put $\delta_2 = o$, and as this assumption would imply that the ether is devoid of density, or mass, it can be seen that Professor Wood's conclusion simply means that a body, or substance, without density may be considered as having uniform density, this

density being *zero*. This answer is perfectly consistent with the fact that Professor Wood while trying to find the density of the ether at any distance from the attracting sphere, left the density of the ether out of the problem altogether, an omission which can hardly be reconciled with the skill of this author. But what seems to me still more extraordinary in the case is the fact that able mathematicians and physicists have carefully read Professor Wood's paper without noticing the above omission. The late Professor Pliny Earle Chase called my attention to this paper twenty years ago in a letter asking me to take the cudgel with him against Professor Wood's criticism of Herschel's method of estimating the density and elasticity of the ether which method he proved to be identical with that of Professor Wood, in a paper published in the *Philosophical Magazine* for September 1886, on "Tests of Herschel's Ethereal Physics." Other occupations at the time prevented me from examining the paper in question, but apart from the above objection, Professor Chase failed to see the unfortunate error which I have pointed out in Professor Wood's analysis.

It may not be out of place to give right here briefly my method of analysis to determine the law of variation of density in a sphere of gravitational gas in equilibrium of temperature. Let w denote the density of this gas at any distance z from the center of the sphere; w_0 the mean density of the concentric sphere of gas whose radius is z; u the mean square speed of the particles of the gas, and k the constant of gravitation. Upon a comparatively small area a at the surface of the sphere of radius z, imagine an elementary prism *adz* whose height dz though very small compared with z, is nevertheless quite large compared with the length of the mean free path of the particles of the gas. Imagine the elementary mass of gas contained in this prism to be bounded all around by an impermeable surface, and let us examine the conditions of its equilibrium within the whole sphere of gas, in accordance with the kinetic theory.

In a radial direction, the prism of gas in question is pressed outward by a pressure $\frac{1}{3}u^2wa$, and inwardly by a pressure $\frac{1}{3}u^2(w-dw)a$. The resultant, therefore, is a pressure $\frac{1}{3}u^2adw$ trying to push the prism away from the center of the sphere. For equilibrium, this resultant must be balanced by the gravitational attraction of the sphere of gas upon the mass

of the prism, which attraction is

$$k \frac{\frac{4}{3} \pi z^3 w_o \times a w dz}{z^2} = \frac{4}{3} \pi k a w w_o z d z,$$

and hence we have

$$\frac{1}{3} u^2 a dw = \frac{4}{3} \pi k a w w_o z d z,$$

or

$$\frac{dw}{w w_o} = \frac{4 \pi k}{u^2} z dz \qquad (1)$$

Assume that the density w varies inversely with some power n of the distance z, and let σ denote the density of the gas at a given distance S from the center. Then we can put

$$w = \sigma \left(\frac{s}{z} \right)^n, \qquad (2)$$

and we can write

$$\frac{4}{3} \pi z^3 w_o = \int_0^z 4 \pi w z^2 dz = 4 \pi \sigma \int_0^z \left(\frac{s}{z} \right)^n z^2 dz.$$

Integrating and solving for w_o we have

$$w_o = \frac{3}{3-n} \sigma \left(\frac{s}{z} \right)^n,$$

or

$$w_o = \frac{3w}{3-n}. \qquad (3)$$

Substituting in (1) we have the equation

$$\int \frac{dw}{w^2} = \frac{3}{3-n} \cdot \frac{4 \pi k}{u^2} \int z d z$$

from which we get

$$w = \frac{3-n}{6 \pi k} \cdot \frac{u^2}{z^2}, \qquad (4)$$

aud dividing this by equation (2) we have

$$\frac{(3-n) w^2}{6 \pi k s^n \sigma} z^{2-n} = 1. \qquad (5)$$

In this expression the only variable is z, and it can easily be seen that such an expression can be satisfied only when n=2, which gives

$$w^2 = 6 \pi k s^2 \sigma = \text{constant} \qquad (6)$$

as it should be. We have also

$$w = \sigma \left(\frac{s}{z} \right)^2 \qquad (7)$$

which shows that in a large sphere of gas, gravitational and in equilibrium of temperature, the density would vary inversely with the square of the distance from the center.

Let us assume that the stellar universe is a finite system of stars moving within a large sphere of gravitational gas whose center coincides with that of the universe. Neglecting the attraction of the stars for one another, a body placed at a distance z from the center would be accelerated towards it by a force

$$k \frac{\frac{4}{3} \pi z^3 w_0}{z^2} = \frac{4}{3} \pi k z w_0 ;$$

and if the body is supposed to revolve around the center of the universe with such a velocity v_0 that the centrifugal force of the body exactly balances its gravitational attraction, we should have

$$\frac{v_0^2}{z} = \frac{4}{3} \pi k z w_0,$$

$$v_0^2 = \frac{4}{3} \pi k z^2 w_0 \qquad (8)$$

From (3) we have $w_0 = 3w$ when we put $n = 2$, and observing that $z^2 w = s^2 \sigma =$ constant we have

$$v_0^2 = 4 \pi k s^2 \sigma = \text{constant}. \qquad (9)$$

Comparing this with (6) we have

$$u^2 = \frac{3}{2} v_0^2 ; \qquad (10)$$

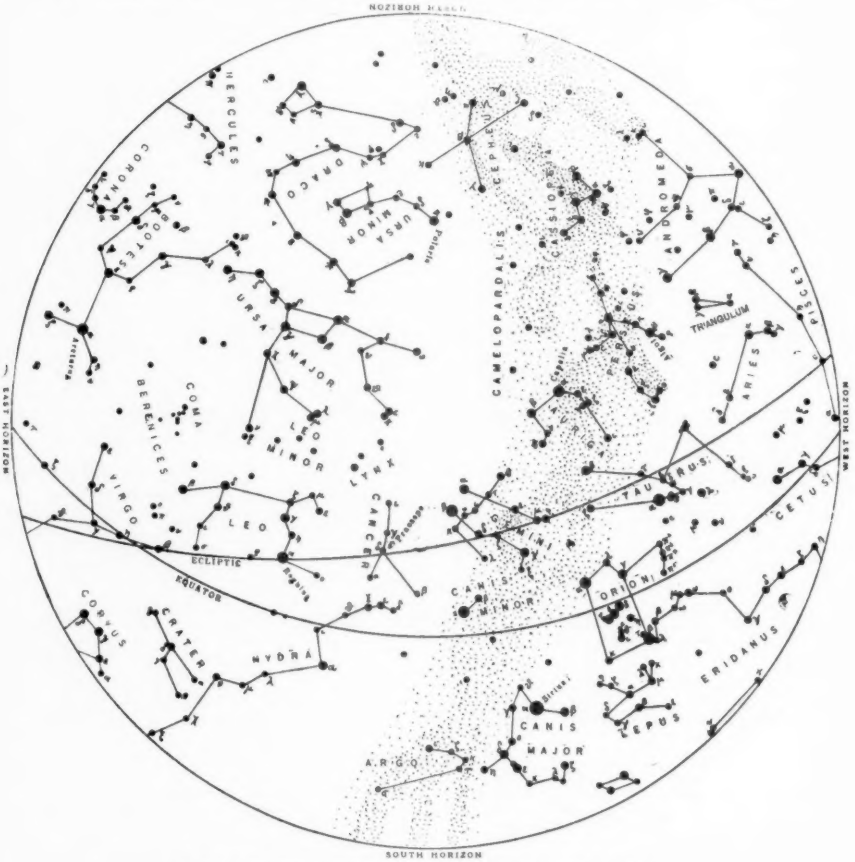
and as v_0 can only be comparable to the mean speed of stellar motion, which according to Kapteyn is about 19.3 miles per second, we can see that the mean square speed of the particles of the gas cannot be much greater than, say, 24 miles per second. A gas whose particles have this mean square speed could not transmit a wave with a velocity greater than 17 miles per second, and a gravitational gas capable of transmitting waves with the velocity of light would produce a mean speed of stellar motion somewhat greater than the velocity of light, that is, about 10,000 times the mean speed of stellar motion given by Kapteyn. This conclusion proves that the hypothesis of a gaseous gravitational ether is inadmissible.

PLANET NOTES FOR MARCH, 1907.

H. C. WILSON.

Mercury will be at greatest elongation, east from the Sun 18° 10′, on March 1. The planet will then be a little north of the Sun and also be at its brightest phase a few days before that time, so that during the last days of February and the first days of March Mercury will be easily seen with the naked eye. One should look for it near the horizon, almost due west, from a half hour to an hour after sunset. During the first week in March the brightness of the planet will diminish rapidly. Inferior conjunction will occur March 17.

Venus is the brilliant morning star, seen toward the southeast in the morning. She has diminished almost half in brilliancy since the beginning of the



THE CONSTELLATIONS AT 9:00 P. M. MARCH 1, 1907.

year but still far outshines all the stars in her vicinity. Her phase is slightly gibbous, increasing to about 0.7 at the end of the month.

Mars will be at quadrature, 90° west from the Sun, on March 9. His course during this month is from Scorpio into Sagittarius along the lowest part of the ecliptic, so that his position is not favorable for northern observers.

Jupiter will be at quadrature, 90° east from the Sun, March 23 and is the most brilliant object, next to the Moon, in the evening sky. He has finished his retrograde movement and will now move eastward until December, passing through Gemini into Cancer.

Saturn will be in conjunction with the Sun March 8 and so will be invisible during the month.

Uranus may be found in the morning in the constellation Sagittarius (see chart in January number.)

Neptune will be at quadrature, 90° east from the Sun, March 31, and so may be found early in the evening in the constellation Gemini. A good telescope and a chart showing the fainter stars in its vicinity are needed in order to identify this planet.

Occultations visible at Washington.

Date 1907	Star's Name	Magnitude.	IMMERSION. Washington M.T.	Angle from N.	EMERSION. Washington M.T.	Angle from N	Duration
			h m	°	h m	°	h m
Mar. 5	49 Libræ	5.4	11 11	138	12 00	262	0 49
7	B. A. C. 6125	6.2	14 57	99	16 04	286	1 07
7	14 Sagittarii	5.6	18 46	93	20 09	276	1 23
8	*o* Sagittarii	3.9	13 32	125	14 20	248	0 48
8	B. A. C. 6561	6.4	16 54	67	18 00	301	1 06
22	ζ Geminorum	4.0	12 04	111	13 04	266	1 00
23	79 Geminorum	6.3	4 59	87	6 28	275	1 29
23	85 Geminorum	5.2	12 09	88	13 11	300	1 02
24	δ Cancri	4.1	10 47	128	12 00	270	1 13
25	B. A. C. 3209	6.3	4 01	28	4 25	348	0 24
30	Piazzi xiii, 174	6.4	5 45	65	6 20	336	0 35

Phenomena of the Satellites of Jupiter.

1907 Central Standard Time, reckoning from noon

Mar. 5	7h 57m	III Tr. In.	Mar. 12	12h 16m	II Oc. Dis.
	9 46	II Oc. Dis.		12 47	I Tr. In.
	10 54	I Tr. In.	13	10 02	I Oc. Dis.
	11 00	III Tr. Eg.	14	6 55	II Tr. In.
	12 08	I Sh. In.		7 15	I Tr. In.
	12 56	III Sh. In.		8 32	I Sh. In.
	13 11	I Tr. Eg.		9 32	II Sh. In.
	14 26	I Sh. Eg.		9 32	I Tr. Eg.
6	8 08	I Oc. Dis.		9 45	II Tr. Eg.
	11 39	I Ec. Re.		10 50	I Sh. Eg.
7	5 22	I Tr. In.		12 24	II Sh. Eg.
	6 37	I Sh. In.	15	8 03	I Ec. Re.
	6 54	II Sh. In.		11 15	IV Ec. Dis.
	7 11	II Tr. Eg.	16	6 53	III Ec. Dis.
	7 39	I Tr. Eg.		6 54	II Ec. Re.
	8 55	I Sh. Eg.		9 57	III Ec. Re.
	9 46	II Sh. Eg.	20	11 57	I Oc. Dis.
8	6 08	I Ec. Re.	21	9 09	I Tr. In.
9	5 55	III Ec. Re.		9 31	II Tr. In.
12	11 48	III Tr. In.		10 27	I Sh. In.

Phenomena of the Satellites of Jupiter.—(Continued.)

Mar. 21	11h	26m	I Tr. Eg.	Mar. 28	12h	22m	I Sh. In.
22	6	25	I Oc. Dis.	29	8	21	I Oc. Dis.
	9	59	I Ec. Re.		11	55	I Ec. Re.
23	5	35	III Oc. Dis.	30	5	33	I Tr. In.
	5	55	I Tr. Eg.		6	42	II Oc. Dis.
	7	14	I Sh. Eg.		6	51	I Sh. In.
	8	36	IV Tr. In.		7	51	I Tr. Eg.
	8	40	III Oc. Re.		9	09	I Sh. Eg.
	9	29	II Ec. Re.		9	37	III Oc. Dis.
	10	51	IV Tr. Eg.		12	03	II Ec. Re.
	10	53	III Ec. Dis.		12	43	III Oc. Re.
28	11	04	I Tr. In.	31	6	24	I Ec. Re.
	12	10	II Tr. In.				

Note.—In., denotes ingress; Eg., egress; Dis., disappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Ephemeris of Jupiter's Sixth Satellite.

[J. E. Martin in *A. N.* 4143]

1907		Satellite — Jupiter Δα	Δδ	Pos. Ang.	Distance
		m s	′	°	′
Feb.	1	−2 44	+16.8	293	41
	6	−3 10	+13.4	286	46
	11	−3 30	+ 9.8	281	49
	16	−3 43	+ 6.1	277	51
	21	−3 49	+ 2.4	273	53
	26	−3 52	− 1.1	268	53
Mar.	3	−3 51	− 4.5	265	53
	8	−3 48	− 7.7	262	53
	13	−3 42	−10.6	258	52
	18	−3 32	−13.2	255	51
	23	−3 21	−15.6	251	49
	28	−3 08	−17.8	248	47
Apr.	2	−2 54	−19.6	244	44
	7	−2 38	−21.2	240	42
	12	−2 22	−22.6	235	40
	17	−2 07	−23.6	231	37

Ephemeris for Physical Observations of the Sun.

1907.	Greenwich Mean Noon. P.		D.		L.		1907.	Greenwich Mean Noon. P.		D.		L.	
	°	′	°	′	°	′		°	′	°	′	°	′
Jan. 1	+ 2	16	−3	7	137	56	Mar. 22	−25	29	−6	58	164	16
6	− 0	10	3	41	72	5	27	25	59	6	46	98	20
11	2	35	4	13	6	15	Apr. 1	26	19	6	31	32	22
16	4	58	4	44	300	25	6	26	27	6	13	326	23
21	7	17	5	12	234	35	11	26	24	5	52	260	24
26	9	32	5	37	168	45	16	26	10	5	29	194	23
31	11	40	6	1	102	55	21	25	46	5	3	128	21
Feb. 5	13	41	6	20	37	5	26	25	10	4	35	62	17
10	15	36	6	37	331	15	May 1	24	23	4	6	356	13
15	17	22	6	52	265	25	6	23	25	3	35	290	8
20	19	0	7	2	199	34	11	22	17	3	2	224	1
25	20	29	7	10	133	43	16	20	58	2	28	157	53
Mar. 2	21	49	7	14	67	51	21	19	30	1	54	91	45
7	22	59	7	15	1	58	26	17	52	1	18	25	36
12	23	59	7	13	296	5	31	16	6	0	42	319	26
17	−24	50	−7	7	230	11	June 5	−14	13	−0	6	253	16

Ephemeris for Physical Observations of the Sun.—(Continued.)

1907	Greenwich Mean Noon. P.	D.	L.	1907	Greenwich Mean Noon. P.	D.	L.
	° ′	° ′	° ′		° ′	° ′	° ′
June 10	−12 12	+0 30	187 5	Sept 23	+25 19	+7 1	238 43
15	10 6	1 6	120 54	28	25 52	6 49	172 44
20	7 55	1 41	54 43	Oct. 3	26 14	6 35	106 46
25	5 41	2 16	348 32	8	26 25	6 18	40 47
30	3 25	2 50	282 20	13	26 26	5 58	334 50
July 5	− 1 7	3 23	216 10	18	26 16	5 35	268 52
10	+ 1 8	3 54	149 59	23	25 53	5 10	202 56
15	3 23	4 23	83 50	28	25 20	4 43	136 59
20	5 37	4 52	17 40	Nov. 2	24 34	4 13	71 4
25	7 46	5 17	311 31	7	23 36	3 41	5 8
30	9 51	5 41	245 23	12	22 27	3 7	399 13
Aug. 4	11 51	6 2	179 15	17	21 7	2 32	233 18
9	13 46	6 21	113 8	22	19 35	1 56	167 23
14	15 34	6 37	47 3	27	17 52	1 18	101 29
19	17 16	6 51	340 58	Dec. 2	15 59	+0 40	35 36
24	18 49	7 1	274 53	7	13 58	−0 2	329 43
29	20 16	7 9	208 49	12	11 49	0 37	263 50
Sept. 3	21 34	7 14	142 47	17	9 34	1 15	197 57
8	22 44	7 15	76 45	22	7 13	1 52	132 5
13	23 45	7 13	10 44	27	4 49	2 29	66 13
18	+24 37	+7 8	304 43	32	+ 2 23	−3 5	0 22

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E , S. W. In computing D (the heliographic longitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′, and the longitude of the ascending node for 1907.0 to be 74° 27′.7. In computing L (the heliographic longitude of the center of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian.

Companion to the Observatory, 1907.

COMET NOTES.

Error in Elements of Comet *g* 1906. Our printer introduced a most unfortunate error in *Lick Observatory Bulletin* Number 103 *after* the final and correct proofs left my hands. He interchanged ω and Ω. The printer's error was noticed by us immediately on receipt of the mailed Bulletin, and I asked him at once to mail a printed slip, correcting the error, to all who regularly received the Bulletin. I read the proof for this printed slip more than a month ago, but it has not yet been mailed. The almost insuperable difficulties in the way of securing labor and materials in this section of the country seem to be responsible for the unfortunate delay. I regret exceedingly that the diagram for Comet *g* 1906, on page 50 of *Popular Astronomy*, has been based upon these erroneous elements. Perhaps it would be well to publish this letter.

W. W. Campbell.

Lick Observatory,
University of California.
Mount Hamilton, January 2, 1907.

Ephemeris of Comet *d* 1906 (Finlay).

1907		R. A.			Decl.			log Δ	Aber.		$1:r^2\Delta^2$
		h	m	s	°	′	″		m	s	
Feb.	1	6	50	28.48	+27	43	20.7	0.07951	9	58	
	2		49	55.25	27	42	20.1	08502	10	6	0.15
	3		49	24.65	27	41	15.3	09053		14	
	4		48	56.63	27	40	6.5	09604		22	0.14
	5		48	31.17	27	38	54.0	10155		30	
	6		48	8.24	27	37	37.9	10706		38	0.13
	7		47	47.81	27	36	18.5	11256		46	
	8		47	29.83	27	34	55.9	11805	10	54	0.12
	9		47	14.29	27	33	30.4	12353	11	2	
	10		47	1.15	27	32	24.1	12900		11	0.11
	11		46	50.37	27	30	31.2	13446		19	
	12		46	41.92	27	28	57.9	13990		28	0.11
	13		46	35.76	27	27	22.3	14532		36	
	14		46	31.84	27	25	44.6	15073		45	0.10
	15		46	30.12	27	24	4.9	15612	11	54	
	16		46	30.57	27	22	23.2	16149	12	3	0.09
	17		46	33.14	27	20	39.7	16684		12	
	18		46	37.78	27	18	54.6	17217		21	0.09
	19		46	44.45	27	17	7.8	17748		30	
	20		76	53.10	28	15	19.4	18276		39	0.08
	21		47	3.69	27	13	29.5	18801		48	
	22		47	16.17	27	11	38.2	19324	12	58	0.08
	23		47	30.50	27	9	45.5	19844	13	7	
	24		47	46.63	27	7	51.5	20362		17	0.07
	25		48	4.51	27	5	56.2	20877		26	
	26		48	24.12	27	3	59.6	21389		36	0.07
	27		48	45.40	27	2	1.8	21898		45	
	28		49	8.32	27	0	2.8	22405	13	55	0.07
Mar.	1		49	32.82	26	58	2.6	22908	14	5	
	2		49	58.87	26	56	1.3	23408		14	0.06
	3		50	26.43	26	53	58.7	23905		24	
	4		50	55.47	26	51	55.0	24399		34	0.06
	5		51	25.95	26	49	50.1	24890		44	
	6		51	57.85	26	47	44.0	25378	14	54	0.05
	7		52	31.12	26	45	36.7	25863	15	4	
	8		53	5.73	26	43	28.2	26345		14	0.05
	9		53	41.66	26	41	18.5	26824		24	
	10		54	18.88	26	39	7.6	27299		34	0.05
	11		54	57.35	26	36	55.5	27771		45	
	12		55	37.05	26	34	42.2	28240	15	55	0.05
	13		56	17.95	26	32	27.7	28706	16	5	
	14		57	0.01	26	30	11.9	29168		16	0.04
	15		57	43.21	26	27	54.9	29627		26	
	16		58	27.51	26	25	36.6	30083		36	0.04
	17		59	12.88	26	23	17.0	30535		47	
	18	6	59	59.30	26	20	56.0	30984	16	57	0.04
	19	7	0	46.74	26	18	33.7	31430	17	8	
	20		1	35.16	26	16	10.1	31872		18	0.04
	21		2	24.54	26	33	45.1	32311		29	
	22	7	3	14.86	+26	11	18.8	0.32746	17	39	0.03

Elements and Ephemeris of Comet *g* 1906 (Thiele.) The following elements of Thiele's comet were derived from observations made by Mr. E. A. Fath at the Lick Observatory on the nights of November 12, 17 and 23, and kindly communicated by Director Campbell. The times of observation were corrected for the interval required by the comet's light to reach the Earth, the comet's distance being computed from the preliminary elements of Morgan.

The brightness of the comet on November 12 is taken as unity. The computation was duplicated throughout by Mr. K. P. Williams.

ELEMENTS.

$T = 1906$ Nov. $20^d.81040$, G. M. T.
$\omega = 8° 13' 4.''9$
$\Omega = 85 48 57.5$ 1906.0
$i = 56 16 13.3$
$q = 1.2133$

Residuals (O—C) $\cos\beta' \Delta\lambda' = -13.''3$; $\Delta\beta' = -2.''2$

CONSTANTS FOR THE EQUATOR OF 1906.0.

$x = r\,[9.748448] \sin(178° 56' 18''.5 + v)$
$y = r\,[9.980934] \sin(115 32 24 .2 + v)$
$z = r\,[9.943269] \sin(35 4 3 .8 + v)$

CONSTANTS FOR THE EQUATOR OF 1907.0.

$x = r\,[9.748430] \sin(178° 57' 46.''9 + v)$
$y = r\,[9.980959] \sin(115 32 47.9 + v)$
$z = r\,[9.943246] \sin(35 4 11.4 + v)$

EPHEMERIS FOR G. M. MIDNIGHT.

1906	True α	True δ	log r	log Δ	Br.
	h m s	° ′			
Dec. 25.5	14 26 6	58 9.5	0.1229	9.9142	0.62
27.5	14 40 23	58 39.9			
29.5	14 54 6	59 3.9			
31.5	15 6 51	59 25.1	0.1356	9.9503	0.50
1907					
Jan. 4.5	15 30 23	59 56.9			
8.5	15 51 3	60 19.1	0.1541	9.9961	0.37
12.5	16 9 3	60 37.1			
16.5	16 24 38	60 53.2	0.1738	0.0381	0.28
20.5	16 37 59	61 9.7			
24.5	16 49 23	61 27.5	0.1941	0.0759	0.21

J. C. DUNCAN.

Bloomington, Ind.
December 20, 1906.

The above note was received too late to be inserted in the January number, but the ephemeris may still be useful in identifying comparison stars.

Ed.

Ephemeris of Comet *g* 1906.

[From *A. N.* 4143]

1907	R. A.	Decl.	log r	log Δ	Br.
	h m s	° ′ ″			
Feb. 1	17 09 31.2	+61 56 24			
2	11 17.7	62 02 15			
3	12 58.8	62 08 18			
4	14 34.4	62 14 31	0.22128	0.12180	0.16
5	16 04.7	62 20 56			
6	17 29.7	62 27 31			
7	18 49.4	62 34 18			
8	20 03.8	62 41 15	0.23149	0.13660	0.14
9	21 13.1	62 48 22			
10	22 17.3	62 55 39			
11	23 16.4	63 03 06			
12	24 10.3	63 10 43	0.24163	0.15061	0.13
13	24 59.2	63 18 29			
14	25 43.0	63 26 24			
15	26 21.8	63 34 28			
16	17 26 55.6	+63 42 39	0.25170	0.16389	0.12

VARIABLE STARS.

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Mar.	4	17
	19	12

RX Aurigae

	(−4	0)
Mar.	8	16
	20	17

Y Aurigæ

	(−0	18)
Mar.	4	14
	8	10
	12	7
	16	3
	20	0
	23	21
	27	17
	31	14

T Monocerotis

	(−7	23)
Mar.	21	6
Apr.	17	6

W Geminorum

	(−2	22)
Mar.	8	21
	16	19
	24	17

ξ Geminorum

	(−5	0)
Mar.	1	14
	11	18
	21	21

V Carinæ

	(−2	4)
Mar.	2	21
	9	14
	16	6
	22	23
	29	16

T Velorum

	(−1	10)
Mar.	4	7
	8	22
	13	14
	18	5
	22	20
	27	12

W Carinæ

	(−1	0)
Mar.	4	19
	9	4
	13	13
	17	22
	22	7
	26	16
	31	1

S Muscæ

	d	h
	(−3	11)
Mar.	1	14
	11	5
	20	21
	30	13

T Crucis

	(−2	2)
Mar.	5	10
	12	4
	18	21
	25	14

R Crucis

	(−1	10)
Mar.	1	22
	7	18
	13	14
	19	10
	25	5
	31	1

S Crucis

	(−1	12)
Mar.	4	5
	8	21
	13	14
	18	6
	22	23
	27	15

W Virginis

	(−8	5)
Mar.	12	19
	30	1

V Centauri

	(−1	11)
Mar.	5	15
	11	3
	16	15
	22	3
	27	15

R Triang. Austr.

	(−1	0)
Mar.	3	8
	6	17
	10	2
	13	12
	16	21
	20	6
	23	16
	27	1
	30	10

S Triang. Austr.

	(−2	2)
Mar.	6	4
	12	12
	18	20
	25	3
	31	11

S Normæ

	d	h
	(−4	10)
Mar.	8	3
	17	21
	27	15

RV Scorpii

	(−1	10)
Mar.	3	20
	7	22
	13	23
	20	1
	26	2

RV Ophiuchi
Minimum

Mar.	2	4
	5	20
	9	13
	13	5
	16	22
	20	14
	24	7
	27	23
	31	16

X Sagittae

	(−2	22)
Mar.	7	8
	14	8
	21	9
	28	9

Y Ophiuchi

	(−6	5)
Mar.	13	9
	30	12

W Sagittarii

	(−3	0)
Mar.	1	3
	8	18
	16	8
	23	22
	31	12

Y Sagittarii

	(−2	2)
Mar.	5	2
	10	21
	16	16
	22	10
	28	5

U Sagittarii

	(−2	23)
Mar.	4	19
	11	12
	18	6
	25	0
	31	18

β Lyrae

	d	h
	(−3	2)
	(−3	7)
Mar.	6	6
	12	22
	19	4
	25	20
	31	6

κ Pavonis

	(−4	7)
Mar.	3	17
	12	20
	21	22
	31	0

U Aquilae

	(−2	4)
Mar.	1	16
	8	16
	15	17
	22	18
	29	18

XZ Cygni

	(−0	3)
	Period 11.2^h	
Mar.	1	13
	2	11
	3	10
	4	8
	5	6
	6	5
	7	3
	8	2
	9	0
	9	22
	10	21
	11	19
	12	18
	13	16
	14	14
	15	13
	16	11
	17	10
	18	8
	19	6
	20	5
	21	3
	22	2
	23	0
	23	22
	24	21
	25	19
	26	17
	27	16
	28	14
	29	13
	30	11
	31	9

U Vulpeculae

	d	h
	(−2	3)
Mar.	4	16
	12	16
	20	15
	28	15

SU Cygni

	(−1	8)
Mar.	2	3
	6	0
	13	16
	17	13
	21	9
	25	5
	29	1

η Aquilae

Mar.	5	9
	12	13
	26	21

S Sagittae

	(−3	10)
Mar.	8	7
	16	16
	25	1

V Vulpeculae
Minimum

Mar.	23	11

X Cygni

	(−6	19)
Mar.	11	7
	27	16

T Vulpeculae

	(−1	10)
Mar.	3	6
	7	16
	12	3
	16	13
	21	0
	25	10
	29	20

TX Cygni

Mar.	11	17
	26	10

WZ Cygni
Minimum
Period 14^h.

Mar.	1	19
	2	23
	4	3
	5	7
	6	11
	7	15
	8	19
	9	23
	11	3
	12	7

Maxima of Variable Stars of the Short Period not of Algol Type.

Continued.

WZ Cygni		RV Capricorni		RV Capricorni		RV Capricorni		VZ Cygni	
d	h	d (−0	h 2)	d	h	d	h	d	h
Mar. 13	11			Mar. 14	22	Mar. 29	6	Mar. 8	17
14	15	Mar. 1	12	15	20	30	3	13	17
15	19	2	9	16	17	31	1	18	11
16	23	3	7	17	15	31	22	23	11
18	3	4	4	18	12			28	4
19	7	5	2	19	10				
20	11	5	23	20	7	VY Cygni		δ Cephei	
21	15	6	21	21	5	(−2	2)	(−1	10)
22	20	7	18	22	2	Mar. 8	17	Mar. 1	17
24	0	8	16	23	0	16	14	7	2
25	4	9	13	23	21	24	10	12	11
26	8	10	11	24	19			17	20
27	12	11	8	25	16			23	4
28	16	12	6	26	14	VZ Cygni		28	13
29	20	13	3	27	11	(−3	6)		
31	0	14	1	28	9	(−2	12)		
						Mar. 4	0		

Approximate Magnitudes of Variable Stars on Jan. 1, 1907.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.		R. A. 1900.		Decl. 1900.		Magn.	Name.		R. A. 1900.		Decl. 1900.		Magn.
	h	m		°	′			h	m		°	′	
X Androm.	0	10.8		+46	27	12.5*d*	S Tauri	4	23.7		+9	44	13.5
T Androm.		17.2		+26	26	14.0*d*	T Camelop.		30.4		+65	57	9.5 *i*
T Cassiop.		17.8		+55	14	12.0*d*	X Camelop.		32.6		+14	56	11.5*d*
R Androm.		18.8		+38	1	14.5*d*	V Tauri		46.2		+17	22	<13
S Ceti		19.0		− 9	53	12.0 *i*	R Orionis		53.6		+ 7	59	10.2*d*
U Cassiop.		40.8		+47	43	12.3*d*	R Aurigae	5	9.2		+53	28	10.0*d*
V Androm.		44.6		+35	6	11.5*d*	S Aurigae		20.5		+34	4	10.0*d*
RR Androm.		45.9		+33	0	14.5*d*	S Orionis		24.1		− 4	46	12.0*d*
W Cassiop.		49.0		+58	1	11.5*d*	T Orionis		30.9		− 5	32	9.5 *i*
U Androm.	1	9.8		+46	11	13.0 *i*	S Camelop.		30.2		+68	45	9.4*d*
S Piscium		12.0		+ 8	24	9 6*d*	U Aurigae		35.6		+31	59	12.8*d*
S Cassiop.		12.3		+72	5	9.1*d*	U Orionis		49.9		+20	10	12.0*d*
U Piscium		17.7		+12	21	11.0 *i*	RR Tauri		33.3		+26	19	10.7 *i*
R Piscium		25.5		+ 2	22	14.0*d*	V Camelop		49.4		+74	30	13.0 *i*
RU Androm.		32.8		+38	10	<14	Z Aurigae		53.7		+53	18	12.5*d*
Y Androm.		33.7		+38	50	11.0*d*	X Aurigae	6	4.4		+50	14	9.2 *i*
X Cassiop.		41.8		+58	46	9.0 *i*	V Aurigae		16.5		+47	45	9.0 *i*
U Persei		52.9		+54	20	11.1*d*	V Monoc.		17.7		− 2	9	9.0*d*
S Arietis		59.3		+12	3	<13.8	R Monoc.		33.7		+ 8	49	11.5
R Arietis	2	10.4		+24	55	8.0 *i*	S Lyncis		35.9		+58	0	9.4*d*
W Androm.		11.2		+40	50	11.0 *i*	X Gemin.		40.7		+30	23	16.0 *i*
o Ceti		14.3		− 3	26	2.5*d*	W Monoc.		47.5		− 7	2	9.7 *i*
S Persei		15.7		+58	8	9.0*d*	R Lyncis		53.0		+55	28	9.0*d*
R Ceti		20.9		− 0	38	10.0*d*	R Gemin.	7	1.3		+22	52	10.5*d*
U Ceti		28.9		−13	35	8.8*d*	R Can. Min.		3.2		+10	11	8.0 *i*
R Trianguli		31.0		+33	50	10.0*d*	RR Monoc.		12.4		+ 1	17	13.0*d*
T Arietis		42.8		+17	26	9.0	V Gemin.		17.6		+13	17	14.0*d*
W Persei		43.2		+56	34	9.8*d*	S Can. Min.		27.3		+ 8	32	9.0*d*
U Arietis	3	5.5		+14	25	8.5 *i*	T Can. Min.		28.4		+11	58	10.5
X Ceti		14.3		− 1	26	11.2*d*	S Gemin.		37.0		+23	41	12.0
Y Persei		20.9		+43	50	9.5*d*	T Gemin.		43.3		+23	59	13.0
R Persei		23 7		+35	20	12.4 *i*	R Cancri	8	11.0		+12	2	9.5*d*
Nov. Per. No.2		24.4		+43	34	13.0	V Cancri.		16.0		+17	36	12.5
T Tauri	4	16.2		+19	18	12.5	U Cancri		30.0		+19	14	13.0*d*
R Tauri		22.8		+ 9	56	12.5	S Hydrae		48.4		+ 3	27	10.5*d*
W Tauri		22.2		+15	49	12.0	T Hydrae		50.8		− 8	46	9.5 *i*

Approximate Magnitudes of Variable Stars on Jan. 1, 1907.
(Continued.)

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R.A. 1900. h m	Decl. 1900. ° ′	Magn.
Y Draco.	9 31.1	+78 18	11.0*d*	TY Cygni	19 29.8	+28 6	13.5*d*
R Leo. Min.	39.6	+34 58	9.0	R Cygni	34.1	+49 58	13.2 *i*
R Leonis	42.2	+11 54	6.8 *i*	RV Aquilae	35.9	+ 9 42	13.5
V Leonis	54.5	+21 44	9.0 *i*	RT Aquilae	33.3	+11 29	13.5
R Urs. Maj.	10 37.6	+69 18	7.0 *i*	RT Cygni	40.8	+48 32	7.8 *i*
S Leonis	11 5.8	+ 6 0	10.0 *i*	TU Cygni	43.3	+48 49	10.0*d*
R Comae	59.1	+11 20	12.5*d*	X Aquilae	46.5	+ 4 12	8.0 *i*
R Corvi	12 14.4	−18 42	10.0*d*	χ Cygni	46.7	+32 40	9.0 *i*
T Urs. Maj.			13.0*d*	RS Aquilae	53.7	− 8 10	13.6*d*
R Virginis	33.4	+ 7 32	10.0*d*	RS Cygni	20 9.8	+38 28	7.8
RS Urs. Maj.	34.4	+54 3	12.0*d*	R Delphini	10.1	+ 8 47	9.4*d*
S Urs. Maj.	39.6	+61 38	8.5*d*	SX Cygni	11.6	+30 46	14.0
RU Virginis	42.0	+ 4 42	10.0 *i*	WX Cygni	14.8	+37 8	9.0 *i*
R Can. Ven	13 44.6	+40 2	9.0 *i*	U Cygni	16.5	+47 35	6.5 *i*
S Bootis	14 19.5	+54 16	8.0 *i*	RW Cygni	25.2	+39 39	9.0
V Bootis	25.7	+39 18	11.0*d*	ST Cygni	29.9	+54 38	13.0*d*
R Camelop.	25.1	+84 17	10.5*d*	Y Delphini	36.8	+11 30	13.5*d*
R Bootis	32.8	+27 10	11.0*d*	S Delphini	38.8	+16 44	11.5 *i*
S Serpentis	15 17.0	+14 40	13.0*d*	V Cygni	38.1	+47 47	13.0*d*
S Coronae	17.3	+31 44	12.0 *i*	Y Aquarii	39.2	− 5 12	8.5 *i*
S Urs. Min.	33.4	+78 58	9.5*d*	T Delphini	40.7	+16 2	13.0
R Coronae	44.4	+28 28	5.8	W Aquarii	41.2	− 4 27	12.5*d*
V Coronæ	46.8	+39 52	12.0	V Delphini	43.2	+18 58	<14
RR Herculis	16 1.3	+50 46	9.5*d*	T Aquarii	44.7	− 5 37	9.0*d*
RU Herculis	6.0	+25 20	11.0 *i*	RZ Cygni	48.5	+46 59	10.0
W Coronae	11.8	+38 3	11.5*d*	R Vulpeculae	59.9	+23 26	9.5*d*
V Ophiuchi	21.2	−12 12	11.5*d*	X Cephei	21 3.6	+82 40	12.0 *i*
U Herculis	21.4	+19 7	12.0*d*	R Equulei	8.4	+12 23	11.0 *i*
W Herculis	31.7	+37 32	12.0 *i*	T Cephei	8.2	+68 5	10.0
R Draconis	32.4	+66 58	9.0*d*	S Cephei	36.5	+78 10	9.0 *i*
S Herculis	47.4	+15 7	10.0 *i*	RU Cygni	37.3	+53 52	8.0*d*
RT Herculis	17 6.8	+27 11	13.0 *i*	RR Pegasi	40.0	+24 36	10.0 *i*
RS Herculis	17.5	+23 1	8.0*d*	V Pegasi	56.0	+ 5 38	9.0 *i*
T Draconis	54.8	+58 14	11.5*d*	RT Pegasi	59.8	+34 38	10.0 *i*
RY Herculis	55.4	+19 29	8.0	T Pegasi	22 4.0	+12 3	9.0
V Draconis	56.3	+54 53	13.0*d*	Y Pegasi	6.8	+13 52	10.0 *i*
RW Herculis	18 1.7	+22 4	14.0	RS Pegasi	7.4	+14 4	9.0 *i*
T Herculis	5.2	+32 0	9.0 *i*	X Aquarii	13.2	−21 24	11.5*d*
W Draconis	5.4	+65 56	9.0	S Lacertae	24.6	+39 48	10.9 *i*
X Draconis	6.8	+66 8	<14	R Lacertae	38.8	+41 51	9.8
W Lyrae	11.8	+36 38	8.5	S Aquarii	51.8	−20 53	12.0*d*
RZ Herculis	32.9	+25 58	8.0 *i*	RW Pegasi	59.2	+14 45	11.0*d*
X Ophiuchi	33.6	+ 8 44	9.0*d*	R Pegasi	23 1.6	+10 0	10.0*d*
RY Lyrae	41.2	+34 34	11.0 *i*	V Cassiop	7.4	+59 8	9.5 *i*
Z Lyrae	56.0	+34 49	9.0 *i*	W Pegasi	14.8	+25 44	8.0 *i*
RX Lyrae	50.4	+32 42	14.0*d*	S Pegasi	15.5	+ 8 22	11.5*d*
RT Lyrae	57.8	+37 22	<13	R Aquarii	38.6	−15 50	10.0 *i*
R Aquilae	19 1.6	+ 8 5	7.0 *i*	Z Cassiop.	39.7	+56 2	13.4 *i*
S Lyrae	9.1	+25 50	<13	RR Cassiop.	50.6	+53 10	11.0 *i*
RU Lyrae	9.1	+41 8	13.0*d*	Z Aquarii	47.1	−16 25	8.0 *i*
U Draconis	9.9	+67 7	13.6*d*	V Ceti	52.8	− 9 31	12.5*d*
W Aquilae	10.0	− 7 13	9.0 *i*	R Cassiop.	53.8	+50 50	12.0*d*
T Sagittarii	10.5	−17 9	12.5	Z Pegasi	55.0	+25 21	10.5 *i*
TZ Cygni	13.4	+50 0	9.0 *i*	U Ceti	57.0	−15 14	8.5*d*
U Lyrae	16.6	+37 42	12.0*d*	Y Cassiop.	58.2	+55 7	11.0 *i*
T Sagittae	17.2	+17 28	9.5*d*				

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar College, Whiteside, Swartz, and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Mar.	2	11
	4	23
	7	11
	9	23
	12	11
	14	22
	17	10
	19	22
	22	10
	24	22
	27	10
	29	21

Z Persei

	d	h
Mar.	3	21
	6	22
	10	0
	13	1
	16	2
	19	4
	22	5
	25	6
	28	8
	31	9

RX Cephei

	d	h
Mar.	5	11

Algol

	d	h
Mar.	1	12
	4	9
	7	5
	10	2
	12	23
	16	20
	19	17
	22	13
	25	10
	28	7
	31	4

RT Persei

	d	h
Mar.	1	13
	2	9
	3	6
	4	2
	4	23
	5	19
	6	15
	7	12
	8	8
	9	5
	10	1
	10	21
	11	18
	12	14
	13	10
	14	7
	15	3
	16	0
	16	20

RT Persei

	d	h
Mar.	17	16
	18	13
	19	9
	20	6
	21	2
	21	22
	22	19
	23	15
	24	11
	25	8
	26	4
	27	1
	27	21
	28	17
	29	14
	30	10
	31	7

λ Tauri

	d	h
Mar.	1	20
	5	19
	9	18
	13	17
	17	15
	21	14
	25	13
	29	12

RW Tauri

	d	h
Mar.	3	16
	6	11
	9	5
	12	0
	14	18
	17	12
	20	7
	23	1
	25	20
	28	14
	31	9

RW Persei

	d	h
Mar.	7	5
	20	10

RS Cephei

	d	h
Mar.	3	7
	15	17
	28	3

RW Geminorum

	d	h
Mar.	2	21
	5	18
	8	14
	11	11
	14	8
	17	5
	20	2
	22	22
	25	19
	28	16
	31	13

R Canis Maj.

	d	h
Mar.	1	19
	2	22
	4	2
	5	5
	6	8
	7	11
	8	15
	9	18
	10	21
	12	0
	13	4
	14	7
	15	10
	16	13
	17	17
	18	20
	19	23
	21	2
	22	6
	23	9
	24	12
	25	16
	26	19
	27	22
	29	1
	30	5
	31	9

Y Camelopardis

	d	h
Mar.	3	15
	6	22
	10	6
	13	13
	16	20
	20	4
	23	11
	26	18
	30	2

RR Puppis

	d	h
Mar.	3	19
	10	5
	16	16
	23	2
	29	12

V Puppis

	d	h
Mar.	1	9
	2	20
	4	6
	5	17
	7	4
	8	15
	10	2
	11	13
	13	0
	14	11
	15	22
	17	9
	18	20

V Puppis

	d	h
Mar.	20	6
	21	17
	23	4
	24	15
	26	2
	27	13
	29	0
	30	11
	31	22

X Carinæ

Period 13^{h}

	d	h
Mar.	1	18
	2	20
	3	22
	5	0
	6	2
	7	4
	8	6
	9	8
	10	10
	11	12
	12	14
	13	16
	14	18
	15	20
	16	22
	18	0
	19	2
	20	4
	21	6
	22	8
	23	10
	24	12
	25	14
	26	16
	27	18
	28	20
	29	22
	31	0

S Cancri

	d	h
Mar.	1	14
	11	2
	20	13
	30	1

S Velorum

	d	h
Mar.	2	21
	8	19
	14	18
	20	16
	26	14

RR Velorum

	d	h
Mar.	1	5
	3	1
	4	22
	6	18
	8	15
	10	11

RR Velorum

	d	h
Mar.	12	8
	14	4
	16	1
	17	21
	19	18
	21	14
	23	11
	25	7
	27	4
	29	0
	30	21

SS Carinae

	d	h
Mar.	1	1
	4	8
	7	16
	10	23
	14	6
	17	13
	20	20
	24	4
	27	11
	30	18

Z Draconis

	d	h
Mar.	1	16
	3	0
	4	9
	5	17
	7	2
	8	10
	9	19
	11	4
	12	12
	13	21
	15	5
	16	14
	17	22
	19	7
	20	15
	22	0
	23	9
	24	17
	26	2
	27	11
	28	19
	30	4
	31	12

δ Libræ

	d	h
Mar.	1	18
	4	2
	6	10
	8	18
	11	2
	13	9
	15	17
	18	1
	20	9
	22	17

Minima of Variable Stars of the Algol Type.—Continued.

δ Libræ

	d	h
Mar.	25	1
	27	9
	29	16

U Coronae

	d	h
Mar.	3	15
	7	2
	10	13
	14	0
	17	10
	20	21
	24	8
	27	19
	31	6

R Arae

	d	h
Mar.	1	3
	5	13
	9	23
	14	9
	18	20
	23	6
	27	16

U Ophiuchi

	d	h
Feb.	1	19
	2	15
	3	11
	4	7
	5	3
	5	23
	6	20
	7	16
	8	12
	9	8
	10	4
	11	0
	11	20
	12	17
	13	13
	14	9
	15	5
	16	1
	16	21
	17	17
	18	14
	19	10
	20	6
	21	2
	21	22
	22	18
	23	14
	24	10
	25	7
	26	3
	26	23
	27	19
	28	15
	29	11
	30	7
	31	3

Z Herculis

	d	h
Mar.	3	2
	4	23
	7	2
	8	23
	11	2
	12	23
	15	2
	16	23
	19	2
	20	23
	23	2
	24	23
	27	1
	28	22
	31	1

RS Sagittarii

	d	h
Mar.	1	21
	4	7
	6	17
	9	3
	11	13
	13	23
	16	9
	18	19
	21	5
	23	15
	26	1
	28	11
	30	21

V Serpentis

	d	h
Mar.	3	8
	6	19
	10	5
	13	16
	17	3
	20	14
	24	1
	27	12
	30	23

RX Herculis

	d	h
Mar.	1	8
	2	6
	3	3
	4	0
	4	22
	5	19
	6	17
	7	14
	8	11
	9	9
	10	6
	11	3
	12	1
	12	22
	13	19
	14	17
	15	14
	16	11
	17	9
	18	6
	19	3

RX Herculis

	d	h
Mar.	20	1
	20	22
	21	19
	22	17
	23	14
	24	11
	25	9
	26	6
	27	3
	28	1
	28	22
	29	19
	30	17
	31	14

SX Sagittarii

	d	h
Mar.	1	22
	4	0
	6	2
	8	3
	10	5
	12	7
	14	9
	16	12
	18	13
	20	14
	22	16
	24	18
	26	20
	28	22
	31	0

RR Draconis

	d	h
Mar.	3	5
	6	1
	8	21
	11	17
	14	13
	17	8
	20	4
	23	0
	25	20
	28	16
	31	12

RV Lyræ

	d	h
Mar.	2	16
	6	6
	9	20
	13	11
	17	1
	20	15
	24	6
	27	20
	31	11

U Sagittæ

	d	h
Mar.	2	13
	5	22
	9	7
	12	16
	16	1
	19	11

U Sagittæ

	d	h
Mar.	22	20
	26	5
	29	14

SY Cygni

	d	h
Mar.	6	20
	12	20
	18	20
	24	21
	30	21

WW Cygni

	d	h
Mar.	3	7
	6	15
	9	22
	13	6
	16	14
	19	21
	23	5
	26	12
	29	20

SW Cygni

	d	h
Mar.	5	13
	10	3
	14	17
	19	6
	23	20
	28	10

VW Cygni

	d	h
Mar.	3	12
	11	22
	20	8
	28	19

UW Cygni

	d	h
Mar.	1	21
	5	8
	8	19
	12	6
	15	17
	19	3
	22	14
	26	1
	29	12

W Delphini

	d	h
Mar.	5	5
	10	1
	14	20
	19	15
	24	11
	29	6

RR Delphini

	d	h
Mar.	1	4
	5	19
	10	9
	14	23
	19	14
	24	4
	28	19

RV Capricorni

	d	h
Mar.	3	5
	6	11
	9	17
	12	23
	16	6
	19	12
	22	18
	26	0
	29	6

VV Cygni

	d	h
Mar.	1	21
	3	9
	4	20
	6	8
	7	19
	9	6
	10	18
	12	5
	13	17
	15	4
	16	16
	18	3
	19	15
	21	2
	22	13
	24	1
	25	12
	27	0
	28	11
	29	23
	31	10

U Z Cygni

	d	h
Mar.	3	4

RZ Cassiop.

	d	h
Mar.	1	6
	2	11
	3	15
	4	20
	6	1
	7	5
	8	10
	9	15
	10	19
	12	0
	13	5
	14	10
	15	14
	16	11
	18	0
	19	4
	20	9
	21	14
	22	18
	23	23
	25	4
	26	8
	27	13
	28	18
	29	2
	31	3

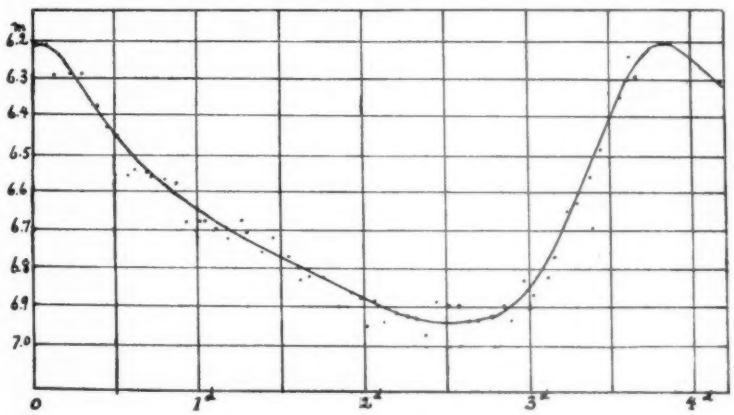
Variable Star RR Draconis.—In Bulletin No. 9 of the Laws Observatory of the University of Missouri Mr. F. H. Seares gives new elements of this variable star, determined from an extended series of photometric observations made by himself and his assistant in the years 1905-6. The elements are

Min. = J. D. 2417026.682 + $2^d.831079$ E, Greenwich M. T.

The star is remarkable for the great range of its variation, the range being apparently more than three magnitudes. It is invisible in the 7½ inch equatorial of Laws Observatory for a period of about two hours in the neighborhood of the minimum. The brightness at normal light is about 10.0^m and the rate of diminution, at the time of its disappearance, a magnitude in a half hour. The light curve appears to be symmetrical.

Variable Star 121.1906 Draconis.—In the same paper Mr. Seares states that minima of the variable 121.1906 Draconis were partially observed by his assistant Mr. Haynes on December 6 and 8 and by himself on December 25. These observations are satisfied by a period of 1.894 days. Values equal to one-third and one-half this amount are excluded by observations on other dates when the variable was found to be of normal brightness. Ordinarily the star is about $0^m.40$ fainter than B. D. + 58°1858, 9.5 mag. The range of variation is 0.8 or 0.9 mag., and the interval of light change appears to be about five hours.

New Elements of the Variable SU Cygni.—In *A. N.* 4141 Mr. M. Luizet of Lyon, France gives new elements of SU Cygni determined by means of a long series of observations by himself in the years 1898-1906. He gives a



LIGHT CURVE OF SU CYGNI.

light curve which indicates that the variation is regular, the decrease of brightness lasting twice as long as the increase. The brightness at maximum is 6.21^m on the Harvard scale and 6.66^m on the Potsdam scale, while at minimum the corresponding numbers are 6.95^m and 7.31^m respectively.

The new elements are

Maximum = J. D. 2414202.826 (Paris m. t.) + $3^d.845612$ E.

GENERAL NOTES.

The Science Year Book for 1907. This new volume for 1907 came to hand a few days ago, from Messrs. King, Sell & Olding 27 Chancery Lane, London, W. C. It is neatly and strongly bound and contains 564 pages, at a net of five shillings. Its contents is in four parts: A full astronomical calendar for the year, with cuts showing the paths of the planets in the constellations, a cut of the Moon with principal surface markings named, key maps to the constellations with four fine colored maps of the principal constellations covering a period of three months each.

This part also contains a brief review of the present state of meteorology, physical and chemical notes, and articles on meteorology, zoology and paleontology, natural history and botany. Then follows a glossary of recently introduced scientific names, a directory of scientific and technical periodicals, a full list of scientific and learned societies and a biographical directory.

The information contained in this part of the book alone is deemed worth its cost.

Then follows the diary for each day of the year, to which is allotted a full page. The first fourth of each of the daily pages contains blanks for astronomical and meteorological records for the day and the rest of the page is blank for the general diary.

After the diary part are blank pages conveniently ruled for a correspondence record, and blanks for a monthly cash account for the year. The volume closes with an index.

We have used this diary for six years, and we find it just what we want in all important particulars. It is commended to all our scientific readers.

The Study of Pure Mathematics. More and more, as the years go on, are we impressed with the value of the study of pure mathematics as a means of mental culture. The reason for this is not hard to find. In the first place one has only to know what the relation of pure mathematics is to almost all applied science to get a definite measure of its importance in that relation,

In the next place, when one has a knowledge of the history of pure mathematics from the beginning through all the centuries of growth to the present state of its development, the impression of its value for mental culture is many fold increased. The eminent scholars who have spent long and busy lives in the examination of this kind of truth for its own sake, as well as for its applications to objects of scientific interest, are the most ardent devotees of its power and usefulness in exact and thorough mental drill. The ordinary student in undergraduate study does not have the advantage of sufficient knowledge in either of these lines of thought. So he can not be prepared to choose for himself in the make-up of his course of study for most effective results in his early training. This is certainly one good reason for the introduction of the group system of studies for the various courses leading to degrees, because it is necessary for students wanting certain lines of work to consult with the heads of departments interested before their plan of work can be definitely settled.

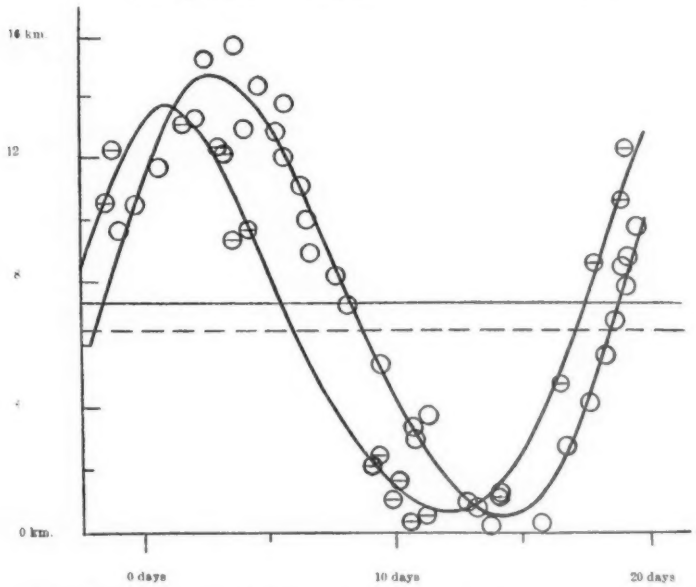
The importance of this must be apparent to all when it is realized what a full preparation of the pure mathematics shall mean to life work in any and all of the applications of science.

Orbit of the Spectroscopic Binary λ Andromedae.—This star is of the fifth magnitude and was announced as a binary by Campbell in 1899. In

the *Lick Observatory Bulletin* No. 105 Mr. Kelvin Burns gives two sets of elements, the one depending upon measures of plates taken with the first Mills spectrograph in 1897, 98, 99 and 1902 and the other upon measures of plates taken with the new Mills spectrograph in 1904-6. A considerable discrepancy between the two sets of elements may be explained possibly by the presence of a third body in the system causing the line of apsides to shift progressively.

ELEMENTS.

	Old Series (1899).		New Series (1905).	
$U =$	$20^d.538$		$20^d.546$	
$\mu =$	$17°.529$	± 0.014	$17°.521$	± 0.006
$T =$	J. D. 2,414,571.81	± 0.37	2,416,683.46	± 0.39
$\omega =$	$336°.2$	± 7.6	$301°.0$	± 7.6
$K =$	6.48^{km}	± 0.19	7.07^{km}	± 0.16
$e =$	0.132	± 0.038	0.086	± 0.018
$V =$	$+ 6.34^{km}$	± 0.13	7.43^{km}	± 0.10
$a \sin i =$	$1{,}810{,}000^{km}$		$1{,}990{,}000^{km}$	
	p. e. single obs.	± 0.050		± 0.51



The diagram shows the velocity curve of the bright component, the barred circles representing observations of the first series and the open circles those of the second series. The dotted line shows the velocity of the center of mass, old series; the continuous parallel line the same for the new series.

Solar Observatory, Mount Wilson, California. The recent report of the Solar Observatory, by Professor George E. Hale is an interesting document, setting forth particularly the present condition and the working plans of this new Institution. Omitting much of interesting detail, we now only give the purpose of this new Observatory, and the names of the persons forming its present working staff:—

(1) The investigation of the Sun (*a*) as a typical star, in connection with the study of the stellar evolution; (*b*) as the central body of the solar system, with special reference to possible changes in the intensity of its heat radiation, such as might influence the conditions of life upon Earth.

(2) The choice of an effective mode of attack, involving (*a*) the application of new methods in solar research; (*b*) the investigation of stellar and nebular phenomena, especially such as are not within the reach of existing instruments; and (*c*) the interpretation of these celestial phenomena by means of laboratory experiments.

(3) The design and construction of a large reflecting telescope and of new types of instruments peculiarly adapted for the purposes in view, with special reference to the possibilities of research through the study of celestial objects under laboratory conditions.*

(4) The accomplishment of the foregoing purposes at a site where the atmospheric conditions have been shown to be exceptionally favorable: Mount Wilson (5,886 feet), in southern California (lat. +34° 13′ 26″, long. W. 118° 3′ 40″).

(5) The furtherance of international coöperation in astrophysical research through the invitation to Mount Wilson, from time to time, of investigators specially qualified to take advantage of the opportunities afforded by the Solar Observatory.

My principal associates on Mount Wilson are Ferdinand Ellerman and Walter S. Adams assistant astronomer. Mr. Charles S. Backus is a general assistant. At the Pasadena office and instrument shop the work of construction is carried on under the supervision of Professor G. W. Ritchey, astronomer and superintendent of instrument construction.

Professor Winslow Upton, Director of the Ladd Observatory of Brown University, and Professor L. H. Gilmore, of Throop Polytechnic Institute were engaged in special work at the Solar Observatory during the summer of 1905.

During 1905 the following expeditions have conducted observations on Mount Wilson in coöperation with the Solar Observatory.

Hooker expedition: Edward E. Barnard, astronomer of the Yerkes Observatory, in charge.

Smithsonian Expedition: Charles G. Abbot, aid acting in charge of the Smithsonian Astrophysical Observatory, in charge; Leonard R. Ingersoll, University of Wisconsin, assistant.

The Systematic Motions of The Stars. At the November meeting of the Royal Astronomical Society, some very important astronomical papers were presented and discussed. The abstract of one on the systematic motions of the stars is particularly noticed. In the last issue of the Observatory, page 440, the substance of that paper by Mr. A.S. Eddington is as follows:—Of late years astronomers who have investigated the proper motions of the stars have generally assumed that if we consider a sufficient number of stars their true motions are at random, and on this assumption the direction of the Sun's motion has been calculated; but Professor Kapteyn has lately examined the proper motions of the Auwers–Bradley Catalogue to find out whether this assumption is approximately true, and concludes that it is incorrect. Relative to the Sun he found two "favored" directions of motion instead of one, and therefore suggested that

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* See the Development of a New Observatory, Publications of the Astronomical Society of the Pacific, Vol. XVII, p. 41. 1905.

there are two systems or "drifts" of stars, and that these two drifts are in motion relative to one another. In this paper the attempt is made to subject Professor Kapteyn's theory to a quantitative test by examining the Greenwich-Groombridge proper motions. The following reasons, among others, seemed to make this desirable. The Bradley stars are all bright stars, of those of the Groombridge Catalogue a large number fall between the seventh and ninth magnitude. The 2500 stars of Bradley's Catalogue cover most of the sky; the 4500 stars of Groombridge are all within 52° of the North Pole.

A "drift of stars" is defined to be a system of stars whose velocities relative to some system of axes are quite haphazard. The velocity of the drift is the velocity of the aforesaid system of axes. The "peculiar" velocity of a star is its velocity relative to that system. The ordinary hypothesis on which discussions of the solar motion are based regards the universe as forming one such drift. It is sometimes further assumed that this is at absolute rest but, of course, referred to the Sun it is in relative motion. A small region of the sky may be taken which can be considered approximately plane, and the stars in it supposed to belong to one drift. Ignoring velocities in the line of sight, a curve may be obtained by drawing the radius vector in any direction proportional to the number of stars having proper motion in that direction.

[A diagram was shown of curves drawn on this principle, one for each of seven regions of the sky into which the area covered by the Groombridge Catalogue was divided. These were discussed separately, and it appeared that in each case these were more consistent with the hypothesis that the stars fell into two drifts than that they were all drifting in the same direction.] Mr. Eddington continued:—It must not be supposed that I claim that two drifts represent completely the phenomena of the distribution of proper motions, and that the discordances are necessarily either errors of observation or the purely accidental departures which the theory of probabilities allows. Local irregularities must be expected. What is claimed for the two-drift hypothesis is that it is a good first approximation, whereas the one-drift hypothesis is no approximation at all.

The analysis of the figures for each of the seven regions, except one which contained too few stars showed the directions of the two drifts in each.
These directions were plotted as great circles ot a globe taking the center of each region as origin, and it was found that the great circles for drift I. (produced backwards) all passed close to the point R. A. 18^h, Dec. $+ 18°$, so that the stars of drift I. have evidently a common velocity relative to the Sun away from this point. The directions of drift II. do not define a point with the same accuracy.
The best position for the apex of this drift is given by R. A. $7^h\ 30^m$, Dec. $+ 58°$.
The positions of these apices agree very well with those found by Kapteyn.
The velocity of the first drift relative to the Sun is very much greater than that of the second, the ratio being about 17:5.
There remains to consider whether the average distance of the drift II. stars is different from that of the stars of drift I. The first system may be a cluster of stars containing the Sun moving relatively to the other system, which might be a background of more distant stars This was investigated by using the *magnitudes* of the proper motions, and the main conclusion arrived at was that there is no appreciable difference in the mean distance of drift I. and drift II. stars.

Causes of Sex in Human Offspring. Professor Simon Newcomb some time ago wrote a paper titled "A statistical inquiry into the probability of

causes of the production of sex in human offspring. The paper was published by the Carnegie Institution at Washington as No. 11. of its series.

Professor Newcomb's prefatory note is as follows:—

The present paper is an attempt to apply a rigorous theory of probable inference to a question of genetic biology, taking statistical data as the basis of the inquiry. If, in making such an investigation, the author may seem to stray outside his professional field, he would reply that the discussion of a biological question was by no means the sole object with which the work has been undertaken. It has appeared to him that the treatment of statistical data generally on a large scale, by the rigorous methods of probable induction, leads one into a field the cultivation of which promises important results to the science of the future; and he hopes the work will show how it is possible by such methods to reach conclusions on questions which elude all direct investigation.

The author has to acknowledge his indebtedness to the Trustees of the Bache fund, who made him a grant to pay the expenses of the necessary examination of genealogical data, and to the Census Bureau, through Mr. W. C. Hunt, chief statistician for population, who supplied statistical data relating to several thousand families culled from the Census records.

A Class of Periodic Solutions of these Bodies with Application to the Lunar Theory. Professor F. R. Moulton has written a strong mathematical paper on the above named theme recently. It is divided into five parts, the introduction, which states the problem, the differential equations employed, the existence of periodic solutions, the practical construction of the solutions, applications to the lunar theory, and applications to Darwin's periodic orbits.

A brief survey of the paper would include a considerable of the introductory fact of the paper which would require more space than we have at present at our command. It is sufficient now to say that the paper will be read by those interested in this theme with interest and profit.

Phenomena of Falling Bodies. Some friend has sent us a copy of a neatly printed newspaper published in Vicksburg, Miss., bearing date of December 15, 1906. Almost the whole of the first page is devoted to an illustrated article, which considers the familiar phenomena of falling bodies near the surface of the Earth.

The author's contention in this paper is, that bodies raised in space and liberated do not fall perpendicularly towards the center of the Earth, nor do they fall with accelerated velocity.

It is not at all surprising that the author should reach wrong conclusions, if one looks at the method of study by which he seeks his proofs and results. He evidently does not grasp the problem in hand at all, and consequently he might as well have had any other conclusion as the one he gets if he had chosen any other wrong method of analysis.

Young students in physics, or old ones for that matter, should not try problems too hard for them especially if such want to publish what they do.

This question of the fall of bodies near the surface of the Earth is satisfactorily determined, and has been for more than two hundred years. It is to be regretted that such erroneous matter should be sent abroad by reputable newspapers to confuse the minds of the uneducated and to lead them to think that well established science is after all nothing more than a confused mass of uncertainty.

A New Theory of the Universe is the title of a booklet of sixty-five pages written by Rev. J. Cosand of Meiji, Gakuin, Tokyo, Japan, preface by Dr. U. N. Wyckoff, and printed by the Methodist Publishing House at Tokyo. The price is 50 sen or 25 cents.

The author of this little book is an educated man, for he has a college degree of the Master's rank, and for this reason it was believed that he might have found something really new to help struggling scientists in explaining the mechanism of the Universe. We have read the book carefully and some parts several times, to be sure that we were getting the author's meaning in his attempt to solve the most difficult problem ever thoroughly considered by the human mind.

In a life time Herschel could only begin work upon it. The amazing genius of a Newton opened the door a little further, and a Darwin with a few others, gifted with powers to reveal nature's secrets, have only been able to stand in the vestibule of the stupendous structure of the material Universe.

To say the least, it would seem a bold undertaking to set aside the causes leading to results now generally accepted which the best scholarship in the world has furnished after ages of study, thought and experimental proof. Our author accepts the results of the science of today, but he attacks the methods by which the results were obtained. That means that he must have a better method of proof for results than Newton and the rest after him knew or could discover. In setting aside the law of gravitation and substituting the condition of heat for it, scientists should expect discoveries of new facts and laws by a better knowledge of heat and its work in nature.

This author says that hot air from the center through its surface in whirling or vortex activity would cause the motions of the planets both in rotation and revolution. He says the motion of ether, in effect, is a prolific source of the energy found in the solar system. As we read what the author had to say about the purpose and work of ether in celestial activities, we wondered if he had considered the long painstaking and skillful work that Michelson and Morley had expended to determine the single fact whether or not luminiferous ether is at rest or in motion.

The assumptions that the author makes for a basis of his new theory, so-called have no scientific foundation to raise even a small probability in its favor. Worse than this, he does not seem to be acquainted with some of the ordinary facts of astronomy. For example page 35: "The Earth's orbit is a circle with the Sun a little to one side of the center. This is called the eccentricity of the Earth." If the planets were in conjunction there would certainly be some disturbance in their motions giving rise to the false belief that they were attracting one another. The author evidently does not understand the law of attraction as shown by Earth and Moon system. He also says the Sun revolves to the west and the planets to the east.

These are only specimens of the bad confusion of his ideas. It is much to be regretted that any reputable publishing house in the world should print such a false worthless and silly book as this, to say nothing of letting their name as publishers appear on it. The Methodist Publishing House in America is one of the best in our land. We do not believe our American Methodist Concern would issue such a book.

Meridian Circle Observations made at D'Abbadia Observatory France. We have received a fine volume of 410 pages in quarto form of meri-

dian circle observations made by W. L'Abbé Verschaffel, Director of the Observatory D'Abbadia á Hendaye (Basses Pyrenees) France. This is volume IV in the series of the work of this Observatory and it gives the appearance of industrious and faithful work.

Elliptic Elements of Comet *h* 1906. In *Lick Observatory Bulletin* No. 108 Mr. Russell Tracy Crawford of the Berkeley Astronomical Department gives another set of elliptic elements of comet *h* 1906, based upon observations by Mr. Fath November 17 and December 5 and by Dr. Aitken December 18. These give the comet a period of 8.24 years.

ELEMENTS

$T = 1906$ Oct. 5.6579 Gr. M.T.			
Epoch = 1906 Dec. 5.68558" "	$\omega = 196°\ 28'\ 36''.2$		
$M = 7°\ 18'\ 06''.8$	$\Omega = 195\ 22\ 37\ .1$	1906.0	
$\log q = 0.209997$	$i = 14\ 53\ 57\ .3$		
$\log e = 9.779872$			
$\log a = 0.610531$	$\omega = 196°\ 28'\ 35''.6$		
$\mu = 430''.736$	$\Omega = 195\ 22\ 27\ 9$	1907.0	
Period = 8.23752 years	$i = 14\ 53\ 56\ .9$		

The ephemeris given extends only to January 23 when the comet's brightness was 0.23 of that on November 17.

Radio-Activity. A very readable article published in No. 3 Vol. 18 of the *Publications of the Astronomical Society of the Pacific*, by Burt L. Newkirk has for its title "A review of certain researches of radio-activity that have a bearing upon astronomical questions. One of some of the most interesting is shown in the few following paragraphs taken from page 292:—

It seems to be quite certainly established that the energy developed by radium, due to the bombardment of the α particles, is not derived from any external source, but is contained in the radium atoms. Accompanying this discharge of energy there is supposed to occur a disintegration of the radium atom. This disintegration occurs at such a rate that half of any given quantity of radium would disintegrate in 2,600 years,* a half of the remainder in the next 2,600 years, and so on. Thus, if a gram of pure radium were put into a closed tube and examined at the end of a period of 5,200 years, it would be found that the tube contained one fourth of a gram of radium and such of the products of the disintegration of the other three quarters of a gram as had not escaped through the walls of the tube. All this time the radium in the tube would be radiating heat sufficient to melt its own weight of ice each hour.

It is clear from the preceding statements that the atoms of the radio-active substances must be regarded as storehouses of comparatively enormous amounts of energy. About two pounds of radium would give off in the course of its disintegration sufficient energy to drive one of our largest ocean liners across the Atlantic at record-breaking speed.

The analysis of the disintegration products of the radio-active elements is one of the triumphs of modern research. It should be remarked that the claim that an actual disintegration of *a chemical element* takes place has been called in question by Lord Kelvin, and has been the subject of an animated controversy among English physicists and chemists.† The result of the discussion was

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* Rutherford, *Phil. Mag.*, October, 1906, p. 367.

† See letter by Soddy, *Nature*, September 20, 1906, p. 516.

simply to bring out the fact that we may either regard the radio-active substances as unstable chemically complex substances or as unstable elements. It is the propriety of calling these substances elements and not the fact of disintegration that has been called in question.

The disintegration theory offers very simple and direct explanations of a multitude of observed phenomena, and I shall proceed to give an account of the observed facts of the "disintegration" of the radio-active substances as interpreted by the theory advanced by Rutherford and Soddy.

The four radio active substances—uranium, thorium, actinium, and radium—disintegrate so slowly (radium being by far the most rapid of the four) that it is difficult, and in most cases impossible, to collect a sufficiently large amount of the disintegration products to make an analysis of them by chemical or spectroscopic methods. The property by which their presence is detected is their radio-activity (for most of the disintegration products are themselves radio-active). It will be remembered that one of the properties of radio-active substances is the ability to discharge an electrified body in its neighborhood. If a current of air is drawn through a tube containing radium and passed into a charged electroscope the electroscope is quickly discharged. This suggests the theory that radium gives off a gaseous disintegration product, itself radio-active, which is carried with the air-current into the electroscope. Other tests confirm this theory. Fortunately enough of this "radium emanation" can be collected to make a chemical examination possible. It is found to be an inert gas of the argon group and of high atomic weight.

Resume of Sun-Spot Observations 1906.

Month	No. of Obs.	N. of Equator No. Groups	N. of Equator Av. Lat. °	S of Equator No. Groups	S of Equator Av. Lat. °	Av. No. at each Obs.	New Groups.
January	8	5	+ 9.7	6	−14.4	4.5	11
February	14	8	10.3	4	10.7	2.4	10
March	8	3	10.3	10	18.5	5.1	13
April	11	5	10.6	2	25.0	1.9	7
May	12	9	10.0	3	16.2	3.0	12
June	5	5	10.1	3	18.2	3.8	6
October	13	1	11.0	4	17.2	0.8	5
November	16	6	10.7	4	15.6	2.0	10
December	8	8	+ 6.7	6	−14.8	3.4	13
Total	95	50		42			87

Average number at each observation 2.71
Average latitude of spots north of equator +9°.7
Average latitude of spots south of equator 16°.4

The Sun was observed six times when no spots were seen:—October 13, 15, 23, 26, 27, November 7.

In the resumé a group appearing upon the eastern limb was counted as "new", even though the same area had been disturbed when upon the western limb a few days earlier.

Observations were made with the eight-inch equatorial. The image of the Sun was projected upon Thomson's Disks, from which approximate latitude and distance from the center can be read at once for each group. The record from January to June was made by Miss Jennie B. Lasby, that from October to December by Miss Elizabeth Schindler.

ANNE SEWELL YOUNG.

Mount Holyoke College Observatory.

Queries. Why is the near approach of Eros so great an event for measurements and parallax? E.

Supposing that our querist understands the meaning of parallax as used in astronomy, a few words will answer his question. The angle of parallax varies inversely as the distance of any celestial object. The less the distance the greater will be its angle of parallax. The planet Eros approaches the Earth within 13,500,000 of miles and Mars when nearest is about 35,000,000 of miles away. Now, since a large angle can be more accurately measured than a small, Eros is preferable to Mars for getting parallax. Eros is a small planet, Mars is comparatively large. The center of Eros can be more readily found than that of Mars. This is another reason why Eros is preferable to Mars for such a purpose. When the parallax of any planet is found its distance from the Sun is known. Then the distances of all the planets are easily found and that of the Sun is known.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the first of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription are sent directly after the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal, promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price Changed. Beginning with last January the price of Popular Astronomy a volume, of ten numbers each, to subscribers living in the United States, its territory, Canada and Mexico was changed to $3.50; the price to all others is $4.00; in each case payable strictly in advance.

Back volumes or single numbers are still on sale at the old prices, $2.50 and 30 cents, respectively.

WM. W. PAYNE,
Northfield, Minn., U. S. A.